Thesis

TURBO TEGELEN II

Lafarge Dakproducten Tegelen

Course	Master of Engineering Maintenance Management Thesis Hogeschool Utrecht Academy for Engineering & Innovation October 2006 - September 2007
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Preface

This thesis is submitted in partial fulfilment for the degree of Master of Engineering in Maintenance Management.
Following more than 15 years of experience in maintaining several different installations, I would like to get a more thorough understanding of the "maintenance" phenomenon.
Research into the possible options available to me revealed that Master of Science in Maintenance Management (now called Master of Engineering) course would ideally complement my own practical experience.
My employer, Lafarge Roofing Benelux, agreed with this and enabled me to attend the course.
I am grateful to my superior Mr. ing. N.Lauret, and my crew lead by Stefan Fransen, Ruud Kersten and Johan Lamerigts. Without their support it would have been very difficult for me to meet the demands of the work involved in addition to my responsibilities at the job.

In this report I often use the word “we”, this because in most of the situations others provided me from data or information. Without their support I had not been able to succeed. Therefore I would like to thank them all and use the word “we” instead of “I”.

Over the past two years I have had the fortune of benefiting from the experience of a number of highly qualified individuals and from the theories of our teachers, shedding light on the subject of maintaining assets. This acquired knowledge has greatly added to my own insights and skills. For their help with my thesis project, I would in particular like to thank Mr. Ir. T.M.E. Zaal, the lecturer of our course, and Mr. Ir. J. Oomens, both of whom have provided valuable assistance as my thesis supervisors.

Last but not least I would like to thank my family who had to share me a lot with this course. To them I would like to say that I am extremely grateful that they gave me the necessary space I needed, to fulfill this course. Above all I would like to thank Gaby for her great support over these last three years.

Summary

The project was carried out by Lafarge Dakproducten Tegelen.
Information was gathered from different disciplines.
In the beginning it looked like Lafarge needed a new kiln. However, having started the project it soon became clear we should not jump to conclusions.

First of all we needed to know what we have to produce. Looking into the future is hard to do, so some assumptions are made. With this data we proceed. Mr dipl. Ing. A. Laumans acted as a sounding board, and in cooperation with him and drawing on his knowledge we got closer to our aim.
Producing far more tiles in Tegelen at an acceptable (lower) cost price.

One of the problems is that Lafarge produces tiles in various ways, making comparisons difficult.
Overall the market is becoming increasingly demanding which means that some of the proposals, which cost money, also have to be carried out in the near future to meet the market demand.

Some problems we defined are:
Producing tiles at different refractory, U-cassettes and H-cassettes, quality aspects.
Producing tiles in different kilns.
Producing products in very small quantities.
And during the project, the sale of 65% of shares to an investment company.

These and other aspects meant that the project boundaries were difficult to establish and subject to fluctuation. In the course the process preconditions changed. However by taking a concurrent approach, we managed to get a clear view of what was required for our purpose.

The result of this project can be summarized as that we have to produce more tiles, the Lingl production needs to increase from a 3-shift to a 4 shift operating plant.
Overhauling or renewal of the old Gibbons kiln is not strictly necessary to achieve the sales budgets in the near future.
However there are more aspects to validate an overhaul like this, for example: the gas consumption, the reliability and safety. Also the strategic position inside the Lafarge Group has to be taken into account.

Therefore whether the pay back time is acceptable, or the only issue, depends on the vision of our group and shareholders in short terms, as well as their vision of how to use their production facilities in the future.

Contents

Glossary and abbreviations

Subject	Dutch	English
TOW	Tunnel ovenwagen	Tunnel kiln car
	Gevelpan	(cloak) verge
	Vorst	ridge
	Tunneloven voor het bakken van pannen	Kiln, tunnel kiln
	Periodiek oven; Huifoven	Shuttle kiln
P	Schuiftempo	Pushing rate
Gr.Rom.	Groot Romaanse pan	Large Roman tile
Kl.Rom	Klein Romaanse pan	Small Roman tile
VH	Verbeterd Hollandse pan	Ruysdael & Breitner tile
OVH	Opnieuw Verbeterd Hollandse pan	Rubens & Bruegel tile
Renova	Renova pan	Renova-model tile
NH	Nieuwe Hollander	NH-model tile
TdN	Tuile du Nord pan	Tuile du Nord-model tile
Kruispan	Kruispan	Boulet tile
CAPEX	Kapitaal uitgaven t.b.v. investering	Capital expenditure
OPEX	Alle uitgaven t.b.v. dagelijkse productie business	Operating expenses
ROI	Terugverdientijd van een investering	Return on Investment
EBITDA	Inkomsten voor rente, belastingen, afschrijvingen en aflossingen	Earnings before interest, taxes, depreciation and Amortization
FTE	Voltijds personeelslid equivalent	Full Time Equivalent

1 Introduction

1.1 General Introduction

This report describes the execution of a revival project called Turbo Tegelen II.
In view of an increasing demand for ceramic roof tiles in the Netherlands and neighbouring countries, Lafarge Dakproducten Tegelen wants to produce many more tiles, with low investment costs.

This goal can be achieved by using re-design principles as well as value engineering / methodical design. The results from this exercise can then be transformed into financial figures and by applying common business management principles we are able to obtain OPEX, CAPEX and an estimate of the return on investment.

As the scope of the project is very wide, and as intervening into the business cannot be done independently, concurrent engineering, working together with different specialties, is the most important skill.
Working concurrently will also shorten the development time.

During the investigation of this project, it became clear that Lafarge had sold its shares for 65% to an investment bank PAI Investment. Although this did not influence the investigation, the maximum payback time decreased fast, from approximately seven years to less than three years.

The goal of this report is to achieve a clear vision of how to handle the old kiln with a view to maximization of output at the Tegelen plant.

This thesis sets out by describing Lafarge Dakproducten Tegelen, and its production process. Subsequently the problem is defined and we will proceed with the rough engineering of the end situation. Finally we will consider some financial data like CAPEX, OPEX and ROI and try to determine what would be the optimal investment for the Tegelen site.

The final decision of how to proceed is of course in the hands of the new owner and will depend on his vision for the future of the plant.

1.2 Introduction into the world of Lafarge

1.2.1 Lafarge S.A.

Lafarge (since 1833) is a world-class company that manufactures building products.
These are divided into 4 divisions:

a)	Cement,	sales € 8 billion ,	38,000 employees
b)	Concrete & Aggregates	sales € 1.3 billion ,	5,000 employees
c)	Gypsum	sales € 5 billion ,	21,000 employees
d)	Roofing products	sales € 1.7 billion ,	13,000 employees

The company has a total of 77,000 employees, in 75 countries, with annual sales of € 16 billion.
The general headquarters are located in Paris; the headquarters of Lafarge Roofing are located in Oberursel (near Frankfurt, Germany).

The company is world market leader in most of its divisions.
Lafarge Roofing group has over 120 local production units worldwide that produce different types of tiles, catering for local market needs. Most of these firms have a long history and their own local name. Not all the firms are in full ownership; many of them are joint ventures where Lafarge is the majority shareholder.

Lafarge's vision has been communicated worldwide through a project entitled:

"Leader for Tomorrow".

This is shown in Appendix I.

Although this is quite a general statement, it is fundamental to our vision.
It is interpreted differently depending on the specific local environment / situation of a particular business unit.

In the Benelux the company is called Lafarge Dakproducten, consisting of 5 production units in different locations:
2 concrete tile works in Tessenderlo (B) and Susteren (NL) and
3 clay tile works in Thorn (NL), Tegelen (NL) and Woerden (NL)

1.2.2 Lafarge Dakproducten Tegelen

Lafarge Dakproducten Tegelen is a site (area of 70.000 m^2) that produces about 23 million clay-tiles a year.
The tiles are produced in 3 plants, the largest plant works in 2 shifts, 7 days a weak.
This means they produce / press clay tiles between 6.00 A.M. and 0.00 hours and fire them in one of the three kilns in about 18 hours.
The "bottle-necks" are the kilns; in 17 hours of production / press time they produce enough tiles for running the kilns 24 hours, the kiln capacity is lower than the press capacity. This is also the case with the Gibbons kiln. For a more detailed overview see Appendix VIII
The main kilns and factory were modernized in 2000 at a cost of about € 18 million.

The roofing tile plant at Tegelen has three production units:

- Gibbons line
- Fittings line
- Lingl line

The Gibbons line and the Lingl line both use tunnel kilns to fire their products.

The names Gibbons and Lingl refer to the company that build the kilns.
The fittings department has no firing facilities and brings their products either to the Gibbons tunnel kiln or the two Lingl tunnel kilns.

At present the production capacity of the whole plant is determined by the capacity of the two Lingl tunnel kilns.

1.2.3 The Production line

In all the three production units the same production lines are used.
This means that the same machines, installations and utilities can be found at the different lines.
The difference between the production units is the type of products which are being produced at the specific lines.
The Lingl line produces the normal tiles, in large quantities, about 18 hours per day, 7 days a week.
The fittings line produces most of the fittings, like verges, ridges, double roll eaves etc.
The Gibbons produces small normal tiles like Tuile du Nord and Boulet-tiles, but they can also produce ridges.
These products are described in the next phrase.

1.2.4 The Product

Our main objective is to produce high quality tiles at the lowest possible cost.
We are dealing here with basic products sold at a low market price, leaving little room to generate sufficient funds for major improvements.
This is in part determined by the presence of a large number of competitors (Wienerberger Gruppe, CRH, Rőben etc.).
With the economy picking up strongly, we need a strategy to ensure the long-term survival of the company in Tegelen. This means a cheap production system and, above all, an increase in output.

The two main kilns are designed to produce tiles and fittings for our main profiles.
The old Gibbons kiln fires fittings, very small tiles (28 per square meter) and miscellaneous products.
Appendix XXIV shows a page from "Technics in detail" [08], giving a small impression of the Rubens & Bruel tile.

See bibliography [8].

Figure 1.1 shows where the different types of tiles are projected at the pitched roof.

To illustrate what a ridge or a verge tile is, a small sketch is drawn. However the precise name of the tile cannot be explained, because the same type of tile can have a different name in other countries, as it is produced by different manufacturers.

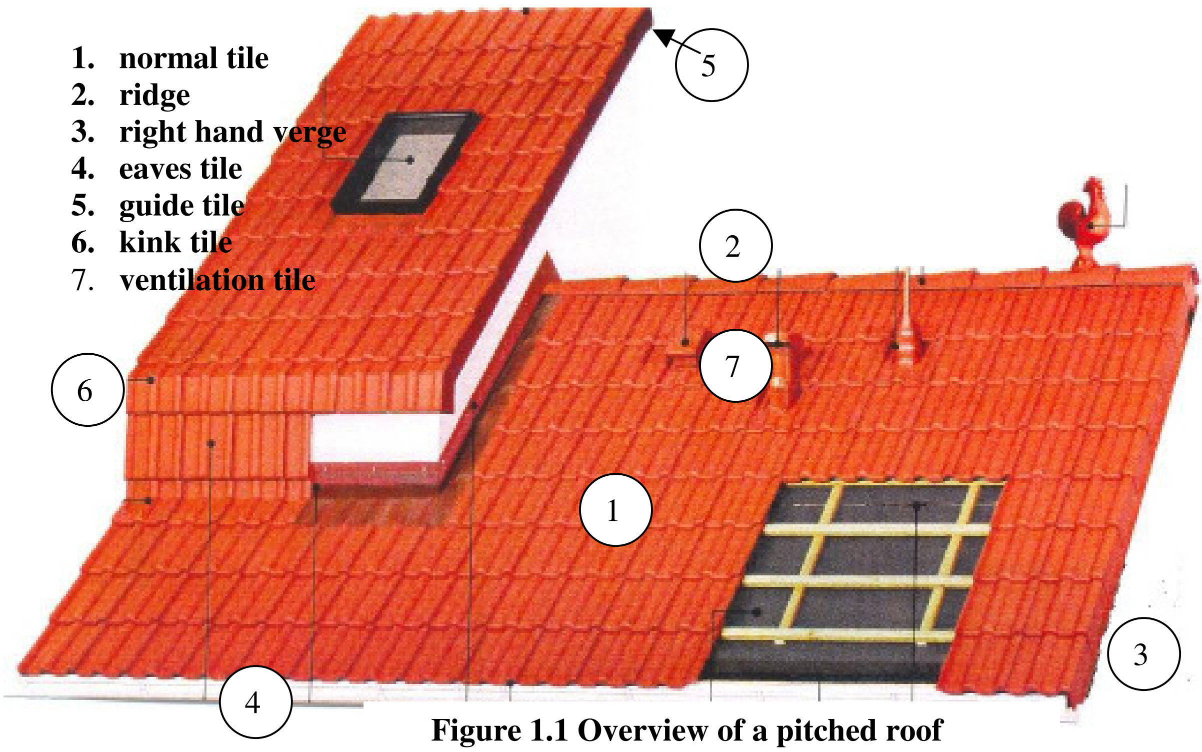


Figure 1.1 Overview of a pitched roof

1.2.5 The production process introduction

As already mentioned the production lines look the same, due to the fact the production processes within Lafarge Tegelen are identical.

To understand the general process of producing tiles a process flowchart is provided below.
For the production process at Tegelen, clay is being purchased from different pits and blended at the site. This minimizes possible product deviations, making their process input fairly steady.

The production process is, concisely, explained below.

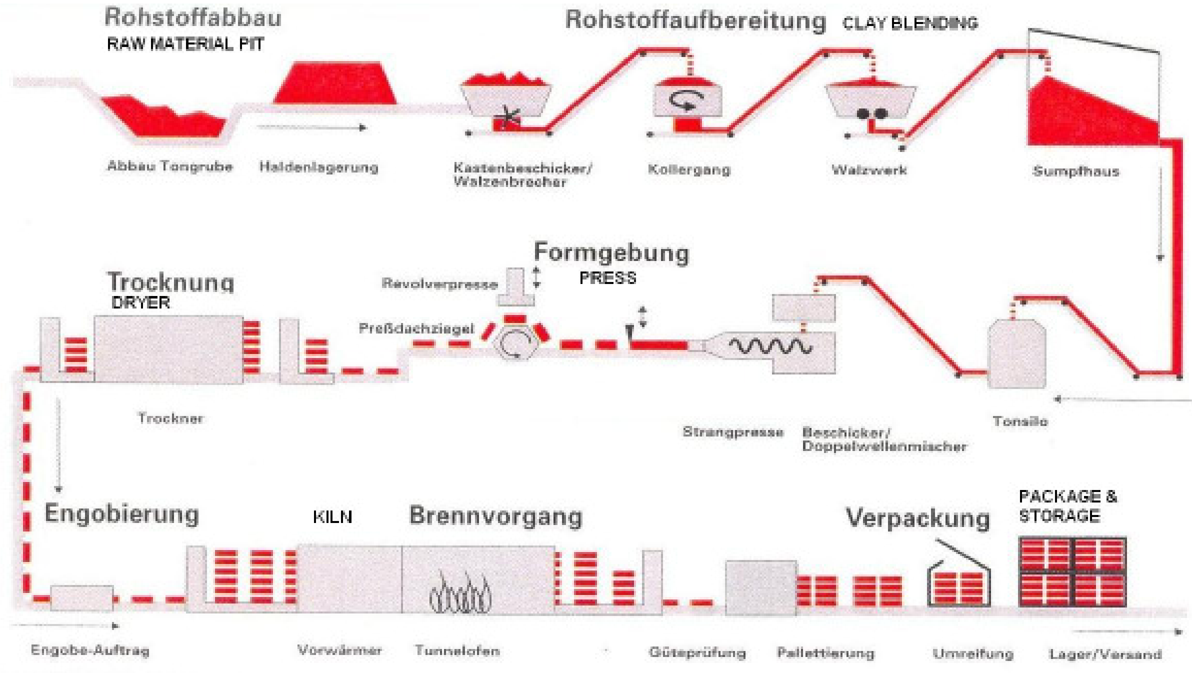


Figure 1.2 flowchart production process

All three units receive clay from one central clay preparation stock cellar.
Different types of clay and sand are purchased which are milled to 1 homogeny clay-mass in our clay cellar. The clay needs to be stored for several weeks before it is ready for use.
Subsequently the clay is cut into small fractions (by pressing it through a sieve), and the air is taken out of the clay-press by creating a vacuum just before the extruder-part. In this manner a clay-cookie (bats) is extruded. With these “bats”, clay tiles are pressed (about 72 pieces per minute).
After pressing, the wet tiles are dried in the drying-chambers where they are, controlled, dried, a process necessary to prevent the water from evaporating in the kiln, because if this happens too quickly, the tile will crack.

After drying, the “green tile” can, if necessary, be sprayed with engobe or glaze. Engobing or glazing is a kind of surface treatment to get a higher aesthetic value. The tiles are transported to the loading section where the kiln-cars are loaded. Those kiln cars are put into the kiln and after a burning time of approximately 18 hours the tiles are ready to be un-loaded and assorted.
The tiles are put in small packs and put on a pallet, before being wrapped and stored in the stockyard

1.2.6 Kiln types

In principle there are three types of kilns in use at the clay tile branch, namely:

a) The tunnel kiln
b) The roller kiln
c) The shuttle kiln

The tunnel kiln is the most common kiln for firing roof tiles. It consists of a long tunnel in which a certain temperature curve is being held. This curve depends on the speed of the kiln cars, the type of clay used and the quality of tiles being produced. Kiln cars which have tiles stacked onto them, are pushed through the fire.
More about the curve is explained in chapter 3.

A complex system of heating and cooling and heat recuperation ensures that the tiles are of the quality required. Due to the stationary situation of the kiln, fuel consumption is lower than that of the shuttle kiln, but much higher than that of the roller kiln.
Tunnel kilns can produce normal red tiles, tiles with engobe and glazed tiles.

The roller kiln, is no longer being built for tiles, most of them are rebuilt into regular tunnel kilns. Anecdotal evidence suggests there are only a few of them left in use e.g. in Thailand and Wienerberger Görlitz (former east Germany).
In these types of kilns, the tiles are transported over ceramic rollers. The fire is underneath and above the tile, ensuring a highly controlled and fast heat exchange. A practical problem is that the high speed of loading and unloading is very critical, especially when a problem occurs at the end of the kiln, when the tiles have to come out either way. So far there have been problems with the bearings (placed outside the kiln).
These are the main reasons these types of kilns are no longer in use for clay roof tiles, although they are still commonly used for floor and wall tiles (it should be noted that those tiles are much lighter and are not complex for their size).

The shuttle kiln is a box that is placed over a kiln car; burners steered by a plc-controller, generate a temperature curve.
Using a shuttle kiln the same tiles as a tunnel kiln can be produced, and in addition “blue” tiles can be produced using this kiln. This is done by stopping the burners at a certain temperature and filling the shuttle with gas. As there is no oxygen the iron oxides inside the tiles are reduced and the free coming oxygen burns with the gas (the temperature is sufficiently high). The new iron oxides have a blue / black colour and as a result the tiles turn blue.
Due to the continuous process of heating and cooling, using a shuttle kiln, gas consumption is much higher than in the case of a tunnel kiln. Therefore, shuttle kilns are built only when producing blue tiles.

This information is gathered in a meeting with Mr. Hingst from Firm Burton ®.
This firm manufacturers all kind of refractory products and sells them all over the world, that is why they know a lot of what kind of kilns is in use nowadays.
Appendix III gives a list of what kind cassettes are in use in what kiln (column 2) and the name of the clay tile manufacturer (column 3).
The conclusion in terms of kilns is that a tunnel kiln is by far the best option to build in Tegelen where “blue tiles” are not produced.
So after this review, we only will talk about tunnel kilns, as this is the system in use at Lafarge Tegelen and the most likely kiln to be used for this type of production.

1.2.7 Kiln process

Clay roof tiles are fired in a continuous process. The standard kiln used for such a process is a tunnel kiln. The first section of the kiln is the heating up section. Here the already dried tiles are heated. Further on, in the middle, the main firing zone is located; here the tiles get heated to about 1030°C. Here the clay is sintered to a piece of ceramic material. The last section is the cooling section. After this section the tile is ready to be inspected and stored, waiting to get loaded.

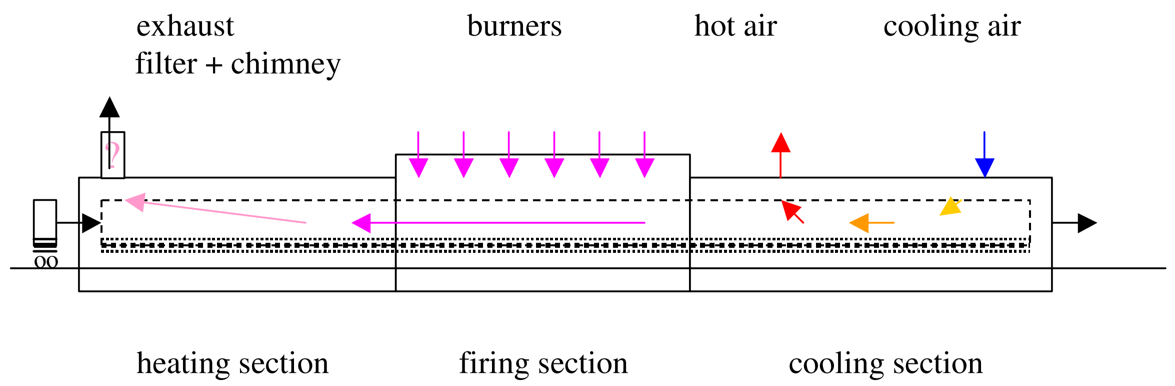


Figure 1.3 cross section of a tunnel kiln

A more detailed kiln process description is provided in chapter 3.

1.2.8 Refractory

The clay roof tiles have to be stacked on kiln cars; this is the conveyer system which transports the tiles trough the kiln. Because of the high temperature the kiln cars need to be protected. Also the "carrier" of the tile has to be resistant to the high temperature. For this purpose they a refractory is used.

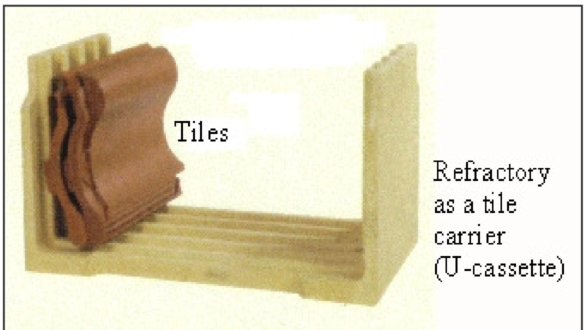


Figure 1.4 U-cassette

Refractory are SiC products that protect "items" from the high temperature or direct heat of burners etc. This means for example bricks of kiln walls.
For the purpose of this thesis, when we talk about refractory we mean the SiC products that are being used to support the tiles in the kiln.
Supporting the tiles is done so that they can be stacked and to avoid the tiles can bend during the firing process.
Over the last decades there have been several different kinds of refractory. Which kind is used depends on how the firing system works. The different types of refractory will be explained later. An extensive overview about refractory is given in Appendix IV.

1.2.9 Refractory configuration

Firing tiles takes place in fireproof tile holders, made of refractory material.
At present 2 different types are in use: U-cassettes and H-cassettes (see figure 1.5 below).

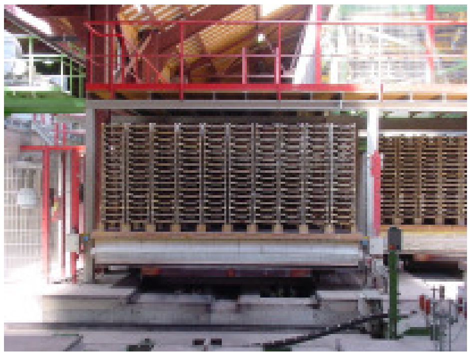


Figure 1.5 Different settings of products on a kiln car {left: U-cassettes; right: H-cassettes}

At U-cassettes, tiles stand on one side, which means a greater number of tiles on a lower weight of refractory, but the downside of this is a higher risk of surface damage and crooked tiles.
At H-cassettes every tile is supported by its own refractory, which means perfect tiles but at a price of higher refractory mass, which is more costly to heat.
A possibility would be for some tiles to be fired at a different kiln on different refractory material, or certain models could be discontinued for cheaper ones to be produced in larger quantities instead.
Perhaps producing a kiln that uses the both kinds of refractory may be a possibility. Ergo, what will be the right configuration of tiles towards refractory towards kilns?

1.3 Background for the thesis project at Lafarge Dakproducten Tegelen

The objective of this assignment is to make an improvement diagnosis for the existing kiln structure.
Lafarge Dakproducten Tegelen has 3 ceramic roof tile kilns and would like to greatly increase its tile production to meet the large increase in demand for tiles.

As financial resources are very limited, the goal is to determine the cheapest way to increase the production of tiles.
We undertook this assignment because we believe that the Tegelen plant has great potential for further development.

During the process of carrying out this investigation, Lafarge has sold 65% of its shares, which has created even greater pressure too increase output.

The bulk of output is generally produced in the main kilns, which already roll at a high speed. However, the complexity occurs when producing the fittings. These (fittings) tiles are far more complex to produce, handle and fire, which is the reason for the complexity of the project.

At the site there are 3 plants / units that produce tiles, and these tiles are transported towards different kilns. So one press produces different tiles and these different tiles are not all fired in the same kiln. Moreover, a large number of tile varieties are produced in very small quantities, but these need to be fired too.

Consequently, a substantial amount of time needs to be invested in producing an overview of what needs to be produced, followed by an overview of where everything needs to be produced.
Once this is known, the required engineering of the system and / or kiln can take place.
The last phase is to evaluate whether there is an acceptable payback time.

1.4 The project

1.4.1 Introduction into the project definition

In the following sections the present market situation and the environment of Lafarge Tegelen is explained, to get a picture of how things are running now and what the moving-spring is for our senior management to come to this thesis subject.

1.4.2 Market situation

The western European market for roofing materials shows a shift towards more and more pitched roofs and fewer flat roofs, in the private home sector, (this does not apply to the Asian and US markets; but this is not relevant for Tegelen). Within this market concrete tiles are increasingly losing market share to clay tiles.

In recent years, the building market, in the Netherlands, has been rebounding from historically low levels of activity. Recent indicators suggest that the market has started to grow and Lafarge wants to be well placed to take advantage of the upswing.

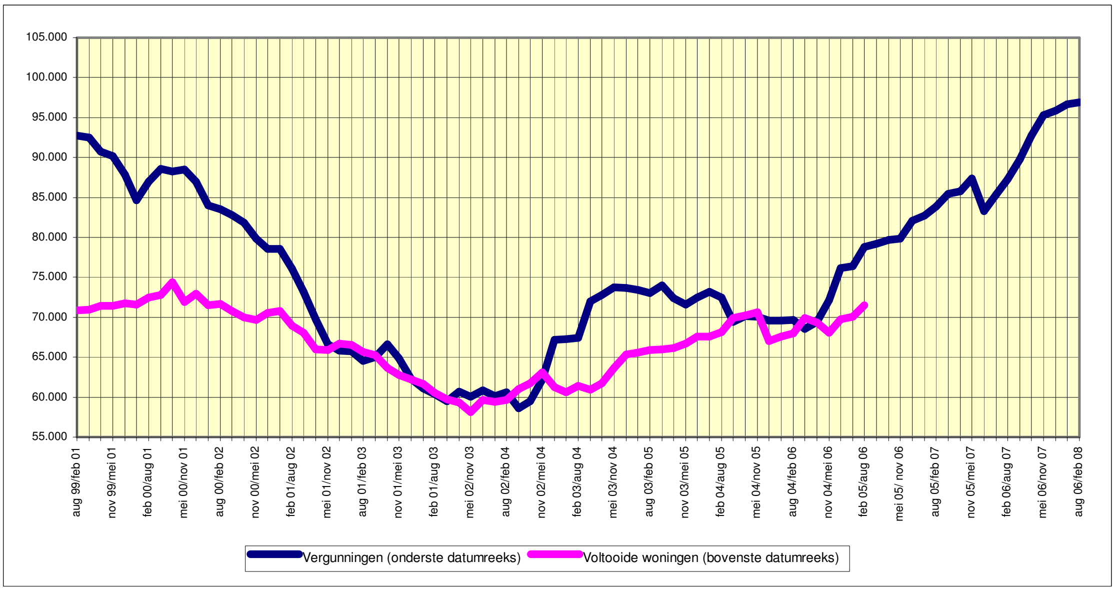


Figure 1.6 Blue line = amount of permits, lower date; Purple line = amount of delivered houses, upper date
Data, Centraal Bureau voor de Statistiek, CBS

This is the motivation behind the company's desire to upgrade its production output.
The graph in figure 1.6 shows newly built houses, which is only a part of the market.
Apart from this part, Lafarge has the renovation part, estimated at approximately 80% of the new built market. We are not permitted to present more detailed information here.
Tegelen is only interested in clay tiles, not other kind of roofing materials.
Sales expects to be able to sell far more tiles than at present. However there is hardly any kiln capacity left, as the kilns are presently running at full speed.
By reshuffling the product mix, we may be able to achieve a more efficient use of our capacity. This would require no investment. But to achieve substantially more output probably the Gibbons kiln (1965) needs to be replaced / rebuild.
The other 2 kilns were (re)built in 2000, and cannot be enlarged.
The marketing & sales department aims at a 10% increase in sales over a 2 to 3 year period.

[13] see bibliography

1.4.3 Present kiln situation

At present, tiles are produced in 3 kilns: two new ones built in 2000, in which several types of tiles can be fired and a 40 year old kiln in which several other types of tiles can be fired.
The old kiln has several disadvantages, namely, higher gas consumption and a low production speed. Moreover this kiln is an arch kiln, whereas the others have a flat ceiling, the arch ceiling is a disadvantage because of its fill effectiveness with its present type of refractory.

Most importantly the heat housekeeping is far worse than that of a flat kiln, due to the airflow.
Because of the poor fill effectiveness, the air flows through easily, which means less heat exchange with the tile and therefore more waste. The tile and its cassette should be the resistance for the air and so the heat will exchange with the tiles.

The Gibbons line is the old Tegelen plant built in 1965 and presently produces special tile-profiles for a renovation market. The old Gibbons tunnel kiln cannot be used to fire the main fittings for the profiles of the Lingl line. This has to do with the kind of cassettes and its pick and place machinery (kiln furniture / refractory / equipment): The Gibbons kiln has U-cassettes; the Lingl kiln uses H-cassettes and U-cassettes.

Due to its high age, this arch kiln will have to be either **replaced, overhauled or extended**.

A big current issue is Lafarge's willingness to sell 65% of the shares of the Roofing division. This means that within a short time a plan of how to make Tegelen more profitable will have to be drawn up. The report must give rise to a performance plan.

1.4.4 Project name

A project called Turbo Tegelen, to increase productivity and therefore reduce cost price, has been underway for more than a year. This has already involved several improvements. However, the main challenge has yet to be met.
This is why this thesis project is called:

TURBO TEGELEN II { TT 2 }

Performance improvement by upgrading our logistic system and perhaps upgrading our oldest tunnel kiln

Figure 1.7 Picture of the Gibbons Kiln

1.4.5 Project boundaries

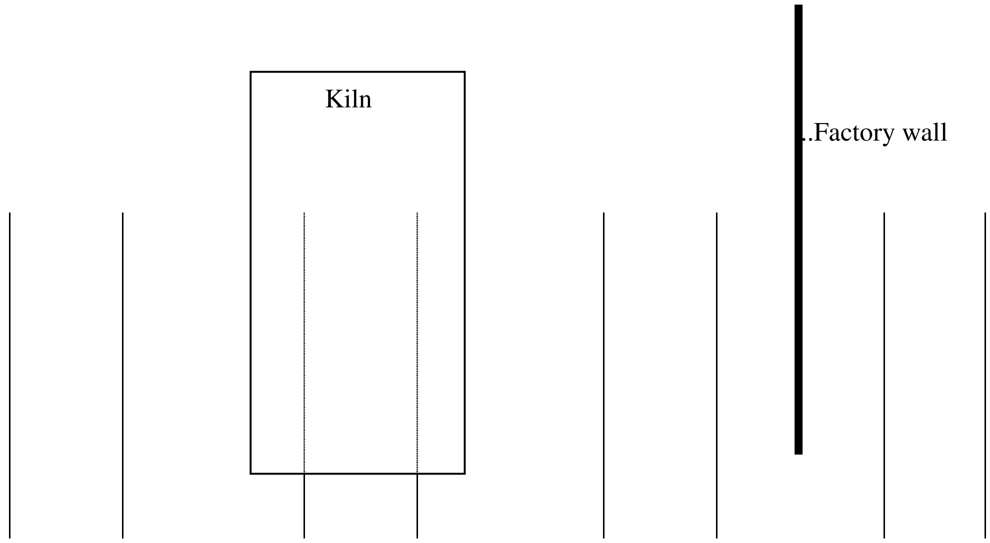
At present the site is running at near full capacity, meaning all 3 kilns run are running at near full speed.
Reshuffling the product mix may enable us to use our capacity more efficiently.
If one of the kilns would need to be replaced it would be the old Gibbons Kiln.
The 2 new kilns were built in 2000 and run at a speed of 70 kiln cars, each, every twenty-four hours, whereas the old Gibbons kiln (1965) runs at a speed of only 14 kiln cars per day {maximum 20 kiln cars per day}. Due to space constraints on the site we cannot expand the 2 new kilns makes it very likely that as we need to replace / rebuilt one kiln that it will be the old Gibbons kiln (1965).

Instead of rebuilding the complete kiln, we first take a look at what should be or should not be replaced. At the Free University of Brussels, Mr Steve Vanlanduit PhD teaches design methodology. Regarding the subject Value Engineering he summarises the essence of the subject as follows: ”*construct as good as necessary not as good as possible”*[09].
Taking his insight into account, we consider several issues concerning our Gibbons kiln.

[09] see bibliography

Kiln car and rails

The kiln cars run over rails and have different dimensions in respect to the Lingl kilns. In case the old kiln would have to be rebuilt, in view of the costs, using the present rails / rail dimensions would be the cheapest option. Otherwise all the 100 cars would need to be replaced as well as the loading and unloading equipment. The costs of replacement per car amounts to about 12K€. (These are the actual costs of 6 kiln cars, which we bought in January 2006).
Because several rails couples are lying next to each other the whole structure and therefore the building + kiln needs to be rearranged when changing these dimensions.



Reshuffling the rail configuration means you have to change the whole system.

Figure 1.8 Overview rail configuration

Boundary 1) use the present rails & cars.

Kiln frame

Our new kilns are about 140 meters long; the Gibbons kiln is about 100 meters long.
Before 2000, the 2 other kilns where also 100 meters long, and had a push capacity of about 35 cars every twenty four hours.
This could mean that our present kiln is already long enough for a higher push capacity.
Therefore using our basic kiln and foundation, would significantly reduce our building costs but most importantly it would reduce the rebuilding time. Moving the kiln to another location on the site would make the whole project too expensive (e.g. extra costs for utilities, chimney, buildings etc).

Boundary 2) use, at least, the basic kiln and its foundation for the new kiln.

Rough cost indication

Rough indication of investment costs:

Proposed extra production of roof tiles: 1,6 million pieces
Expected contribution margin is about € 300 / 1,000 tiles => € 580 K.
In addition, there would be savings arising from lower gas consumption, lower labour costs etc.
Currently the maximum payback time, within Lafarge, for this kind of project is about 8 years.
Ergo, the maximum investment would be about € 5,000 K.
This is merely meant to be an indication as to whether we are on the right track.

Boundary 3) indication of investment costs is about € 5,000 K.

1.4.6 Final project definition

After some consideration this project contains an investigation of what can be done by reshuffling the product flow perhaps combined with adaptation to the Gibbons kiln, assuming that we keep the present kiln rails, kiln cars as well as the foundation of the Gibbons kiln, to obtain a higher output, which in turn would mean higher profit.

The costs / benefits of the proposed solution(s) can be estimated by using CAPEX and OPEX sheets.
Finally an extensive DCF (depreciated cash flow) calculation must provide senior management with sufficient decision-making information.

1.5 Description of the research problem

- What would be the optimal combination of tile production in Tegelen? I.e. what tiles should be produced in what kiln at what refractory
- What kind of kiln would they require or what adaptations would have to be made?
- What would be the cost of the proposed modification?
- Estimates of CAPEX and OPEX.
- What would be the Return On Investment (ROI)?

The conclusion of the study could be that making no changes would be the best solution. What is required is a program based on sound analysis to ensure Tegelen succeeds in the near and medium term.

1.6 Objectives of the thesis

The intended outcome of this project is a performance plan that addresses the questions mentioned in 1.5.
It needs to be established not only what needs to be done physically, but even more importantly what is the expected Return On Investment, and how sensitive are the figures of this calculation to changes in the assumptions.
If assumptions are changed, how would this affect the ROI?
First of all we need to determine what is the right methodology to tackle this problem

1.7 Methodology

In this chapter, we will explain what kind of problem solving techniques are available for our case. And above all, what system / methodology will be followed to get a well-founded answer to the thesis subject. Weighing off financial considerations against each other is an important element of this project.
This thesis project consists of two stages: First of all it consist of a study into alternative ways of producing tiles and logistic possibilities. Subsequently these options have to be combined and interpreted financially.

On the whole the emphasis of our study will be more on managerial and production aspects than on aspects of mechanical design. The first part of the study will be an attempt to find the best way of redesigning of the existing tile production process.
The subsequent parts of the study will consider how we can achieve our objectives; principles of business management / economics will be applied to legitimize the investment. We are applying managerial methodology as the backbone of this study and we are using redesign methodologies to determine what would be the best strategy to achieve an optimal tile production process.

1.7.1 Introduction to the methodologies

In our study we are taking a managerial / financial approach to the redesign process, which entails a search for an appropriate Managerial (Redesign) Methodology.
The book, Managerial Methodology; management of research, by Prof. Dr. Ir. A.C.J. de Leeuw offers a research method for managerial problems.
The basic methodology we use is by Prof. Dr. A.H. van der Zwaan. Herein the phases of research are split up into 6 items.

1. Problem introduction
2. Problem definition
3. Set up of the research plan
4. Data collection
5. Research / Analyse phase
6. Report

This method will be used as the backbone of our research and as a structure for our report.

When considering our project it becomes apparent that we are also faced with a redesign problem.
We have an existing tile production process which we want to upgrade and bring to a higher efficiency level. This requires redesign efforts.

For this purpose the basic system is explained in Redesign Methods and Techniques. This methodology finds its origin in the subject of mechanical engineering and this method can easily be transformed into a redesign process. The aspects of redesign are as follows:

Concept engineering
- Gathering information
- Concept generation
- Morphological analysis
- Estimate technical feasibility
- Concept selection

Embodiment engineering
- Embodiment checklist
- Control reliability
- Mathematical modelling
- Physical prototyping
- Design for X

[10] see bibliography

As this study is being undertaken to assess the financial viability of redesign, we are not her considering the embodiment engineering aspect. Even at a later stage this would be unlikely to be carried out by Lafarge, as the company would “buy” a kiln as a turnkey project in which case the technical details would be engineered by the supplier.

The concept engineering part will be divided and determined by certain aspects of Van der Zwaan’s methodology, which points to substantial synergy effects.
Recombining the two methodologies suggests the following approach:

1. Problem introduction
2. Problem definition
3. Set up of the research plan
    a. Methodology selection
4. Data collection:
    a. Gathering information
    b. Concept generation
    c. Morphological analysis
5. Research / Analyse phase:
    a. The first part will focus on the process technical aspects
        I. Estimate technical feasibility
        II. Concept selection;
    b. The second part will deal with the financial analysis
6. Report:

In essence we adopt Van der Zwaan's approach as the results of our study meant to be used for managerial purposes.

Concept generation and morphological analysis can be done in many different ways, e.g. following Pugh or Van den Kroonenberg.
The approach of Van de Kroonenberg seems to be very appropriate for our purpose as he uses the goals of the project as guiding principle throughout the design process.
Our project is guided by achieving an increase in production at the lowest possible costs (performance improvement section 1.4.4).
Although basically this methodology is used for the redesign of products, we will apply these steps to the redesign of a process / process flow.

The steps of the methodical design process of van den Kroonenberg are as follows:

1. goal
2. problem definition phase
3. function
4. what way to achieve
5. phase
6. structure
7. forming
8. the result

The methodical design process according to H.H. van den Kroonenberg [01]

The last step in the methodology used is the financial analysis; i.e. what are the expected revenues of the different proposals.
This financial analysis of the project will be presented in a Discounted Cash Flow sheet. This is an internationally accepted system of calculating pay back time, based on the Net Present Value (NPV) of a project.
Apart from its universal use, it is also the standard method used by Lafarge standard to compare different investments, worldwide.

1.8 Summary

To be able to carry out a sound analysis of this project, a methodology is designed by combining established approaches from the disciplines of Management and of Product Redesign.
As a basis we use the Van der Zwaan's, Methodical Management method. Into this we integrate elements of Redesign Methods and Techniques for our concept generation and the morphological analysis.
Our way of thinking in these research stages follows the Van de Kroonenberg approach, namely:
"Start with your goal and find your way back to the solution(s)".
Finally the different concepts are being weighed off against each other in a financial comparison according to the Depreciated Cash Flow method.

Having established the method of analysis for our project, we will now embark on the actual research for our project, strictly following the methods outlined above.

2 Data collection in respect to the Lafarge tile production process redesign

2.1 Introduction

Below we set out the subsequent phases in the redesign process, explaining all the steps.

We have several different types of tiles, which will not be changed for the purpose of this project.
Perhaps one type of tile could be discontinued, namely the large Roman tile (Gr.Rom.).
Further market research will not be undertaken. Production of a new type of tile will start at the end of 2007. The pre-project of design has already started.

Benchmarking about what kind of refractory or what kind of kiln would seem very beneficial.
Given we have a large number of ceramic roof tile factories, benchmarking is straightforward.
Vis-à-vis competitors it is very difficult to undertake research regarding refractory etc.

The redesign process will be steered as mentioned in chapter 1.7.1, summarized as follows:

1. Problem introduction
2. Problem definition
3. Set up of the research plan
    a. Methodology selection
4. Data collection:
    a. Gathering information
    b. Concept generation
    c. Morphological analysis
5. Research / Analyses phase:
    a. The first part will focus on the process technical aspects
        I. Estimate technical feasibility
        II. Concept selection;
    b. The second part will deal with the financial analysis
6. Report:

Item 1 till 3 are already explained, we will now carry on with the data collection.

2.2 Gathering information

The concept generation process starts with gathering information. Information sources are benchmarking, analysis of similar products, published media, people (manufacturers, experts) and the internet. These sources are also used for this project.

Before collecting data we have to determine what data we need to investigate to be able to give an answer to the thesis question(s).

In the first place we have to see what can be changed in case of this project.

Basically we consider:

- Amount of tiles which have to be produced (2.2.1)
- Production capacity (2.2.2)
- Kiln structure / dimensions (2.2.3)
- Kiln firing process (2.2.4)
- Types of refractory (2.2.5)
- Type of tiles (2.2.6)
- Logistic system (2.2.7)

2.2.1 Quantity of tiles which to be produced

In the last 4 - 5 years production has risen from 15 million to 20,5 million (2007) normal tiles a year. The expected market rise for Lafarge Tegelen is estimated at 23 million normal tiles. As a result of some recent switches in production locations within the Lafarge group, a further enlargement of production capacity in Tegelen in the next 5 years is not expected.

Production upgrade

If case of implementation of the above plan, a certain production output increase would be achieved. This must be calculated as more tiles mean more fittings etc, which would require a higher capacity for the 3rd kiln.

The design of the renewed kiln must have at least the capacity to produce the fittings related to this increased tile output, although an extra additional capacity (say 10%) would be preferable as we also expect an increase resulting from optimising the 2 Lingl kilns and perhaps as a result of “de-bottle necking” the system.

Estimate production ratio data

Before considering the Gibbons kiln, we have to determine the estimated production volumes.
The seemingly obvious way to get those data would be to use a sales list of the last 3 years. However as this list is hard to read, due to the poor description of the tiles, we use the production volume lists of 2004, 2005 and cum10 2006, out of our SAP [management system] system.
Although production is not equal to sales, accumulated over 3 years, the differences are negligible.
At this time the stockyard is quite empty, indicating that all products produced are sold quickly.
On the other hand, there has been a change of product models over the last few years, and there will be a further model change next year. So depending on the variation / deviation in data, we can probably say whether the figures are adequate for our purpose.

2.2.2 Production capacity

If tiles are going to be fired at the Gibbons kiln, it is likely that they also have to be dried / cured there. Extra handling is always an efficiency loss.
Therefore, the press capacities of the several presses are listed in Appendix VI; the last figure in each matrix gives the net capacity per press after drying and firing.
The miscellaneous products are dried at other places, and are put into the kiln on demand, rather than as an iron stock figure.

In Appendix VIII a process flow chart is drawn with the single capacities of all major production units.
From this it can be clearly seen that the Gibbons kiln has the lowest production capacity of all the 3 kilns. Even lower than the maximum production capacity, which has to be fired in the Gibbons, kiln. This is a reason more why it is likely that this kiln will have to be upgraded.

2.2.3 Kiln structure / dimensions

At the site in Tegelen, Lafarge has only tunnel kilns. However they have 2 different concepts in use.
The 2 new kilns are rectangular, making it easy to stack the kiln cars so that they have an optimal filling degree of the kiln. The kiln cars are stacked with refractory loaded with tiles. Because of the high filling degree, the air inside the kiln is restricted to flow freely. This means it has to go along the tiles, resulting in a good and steady heat exchange.

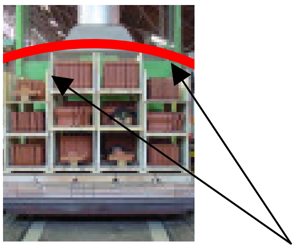


Figure 2.1 arch kiln

The third kiln is an old kiln with an arch ceiling. The advantage of the high filling degree of the aforementioned kiln is lost as a consequence. This means that the airflow is hard to control which results in higher energy consumption and lower production / firing speed.

2.2.4 Kiln firing process

To explain in general terms what a kiln is and how it functions, chapter 3 explains the tunnel kiln and provides answers to the questions of what can / has to be done with the dimensions and the firing process.

2.2.5 Types of refractory

There are a large number of producers of refractory. The majority of them produce only plates or bricks for cladding walls or kiln cars. Only a few produce refractory as meant above (tile carriers).
Some well-known brand names are: Burton®, Imerys® and Calderys®.
Because Lafarge buys a lot of refractory, world-wide, from Burton's, there had been a meeting with Firm Burton®, Mr. Hingst.
Burton® produces several types of refractory (the tile carriers as well as the cladding bricks), an extended overview is added in Appendix IV.
U-Cassettes; H-Cassettes; angle carriers and stack pillars.

Explanation of types of refractory:

Stack pillars are mostly used when the tiles stand on their edge.

Advantage: less refractory, less weight, less fuel consumption
Mostly one layer firing, fast system

Disadvantage: tiles are only loosely stacked, if one falls many of them will follow
Tiles need to be very flat
Engobe or glaze severely pollutes the kiln car

Neutral: low wide kiln

Angle carriers are mostly like stack pillars, except that tiles are supported so they will not fall easily.

U-cassettes; the tiles are stacked in an "open box"; here they also stand on their edge.

Advantage: cassettes can easily be stacked
More weight than stack pillars although relatively less weight than H-cassettes
Different products can be stacked in 1 type of cassette
Pollution can easily be cleaned, outside the production line
Engobe or glaze will not pollute the kiln car

Disadvantage: tiles stand loose, if one falls many inside the cassette will fall
Tiles need to have a flat side

Neutral: height and width of cassette can be varied depending on the car / kiln.
By doing so, the measurements of the kiln can be manipulated
(e.g. no need for a low wide kiln)

H-cassettes, here every single tile has its own carrier.

Advantage: cassettes can easily be stacked
Pollution can easily be cleaned, outside the production line
Optimised carrier for the tile, so the tiles will not bend
Engobe or glaze will not pollute the kiln car

Disadvantage: greater weight than U-cassettes
Different products, mostly, cannot be stacked in 1 type of cassette

All the types of refractory are commonly used. However, because of quality aspects red, engobe or glazed tiles must not touch each other in the kiln during firing, as this results in spots on the tiles where they are in contact with each other. In Western Europe this is no longer acceptable practice.
To reduce this problem, some manufacturers use wax on tiles, so the spots cannot be seen as easily.

In light of the above, the H-cassette is the right cassette for us to produce normal tiles, ridges and verges. Special tiles however will be fired at U-cassettes and to avoid touching each other only a few pieces are stacked per cassette.
Buying cassettes for every type is very expensive and because they will not be used in every cycle the logistics of stacking the cassettes not used and placing the right ones would entail a very complex logistical system and therefore too expensive.

Given that we will keep our present kiln cars, (1.4.5 project boundaries), we need to see what the refractory layout can be at the Gibbons kiln cars, now that we know that we have to replace most of the U-cassettes with H-cassettes.
In Appendix XI we see 3 possible layouts
These 3 layouts show the different spaces between the refractory rows.
The space between the cassettes needs to be at least 250mm (info Fa. Lingl, Neu Ulm Germany). Otherwise the flame of the burner can damage the tiles or cassettes. Towards the pushing rate it is preferable to have a burner between all the cassettes. In this way one achieves a more homogeneous temperature division in a shorter time, which means a higher pushing rate.
In summary that is why there is only one possible layout namely 3 rows of refractory at 1 kiln car.

Appendix XII shows the physical dimensions of the refractory. We want to use as much as possible refractory which is already available. This to keep our investment costs as low as possible.
With the dimensions of the refractory and the dimensions of the kiln cars we can determine how many cassettes can be placed at a kiln car, per type of refractory.

2.2.6 Different types of tiles information

At the site of Lafarge Tegelen 3 different types of roof tiles are produced:

1) Main tiles or normal tiles
2) Small normal tiles
3) Fittings; verges and ridges etc.
4) Miscellaneous, e.g. ventilation tiles, guide tiles etc.

See figure 1.1

The following matrix gives an overview of all the different tiles this study deals with.

Group	assortment	Description	actual production line
main tiles or normal tiles	standard tiles for cladding large roof areas { 12 till 16 tiles / square meter }	several types in several colours	Lingl line
small normal tiles	standard tiles for cladding small roof areas { 28 tiles / square meter }	Tuile du Nord / Boulet-tile in several colours	Gibbons
Fittings	verges; left and right side of the roof Ridges; cladding top sight of the roof Eaves tiles guide tiles Double roll tiles 2/3 tiles	fittings, produced in fairly Large amounts to complete the roof, per type in several Colours	Fittings Gibbons/Fittings Fittings Fittings Fittings Fittings
Miscellaneous	left hand guide tiles Right hand guide tiles TdN / Boulet verges kink tiles left hand eaves tiles Right hand eaves tiles begin ridges end ridges ventilation tiles etc.	fittings, produced in small amounts to finish the total Roof	Gibbons Gibbons Gibbons Fittings Fittings Fittings Fittings Fittings Fittings
Show tiles	types of king post (piron)	Extra's for the outstanding Roof	out sourced

Table 2.1 overview different types of tiles

A rough sub-categorisation of tiles can be made as follows:

Main tiles, these are produced in large quantities, normally at high speed in a well-utilised plant.

Fittings, these are the tiles that complete the pitched roof, e.g. ridges and verges but also guide and under-tiles. These are mostly produced in small quantities, typically 1 – 2 % of the main tiles.

Miscellaneous, these are mostly hand made tiles produced in very small quantities. For instance a -guide wall abutment tile- or a -ventilation tile- etc, where only a few are used per roof.
This means that typically these tiles are hand-made, meaning making them very labour intensive, and in view of the low quantities automation of these production processes they have no payback time.

Because of quality aspects most of the tiles will be fired in H-cassettes. Only few types (miscellaneous) will be put into U-cassettes

The show tiles are not produced in Tegelen; we buy them from companies who are specialized in manufacturing those clay products.

The complex shape the fittings and the miscellaneous tiles causes the airflow inside the kiln to become more turbulent, which means less control of where the hot air will penetrate and thereby how the tile is fired;
This in combination with its greater weight means they cannot be heated as fast as a normal tile; different temperature and different heat consumption can result in cracks.

In light of the above, it would be preferable to produce only one category of tiles in one specific kiln.
This would enable us to optimise in one kiln the car loading, pushing rate, the cassette type and the firing process. This according to the type of tiles being produced.

This could mean that in one Lingl kiln only the normal tiles will be fired on H-cassettes. In the other Lingl kiln normal tiles on H-cassettes and small tiles on double H-cassettes can be fired. In the Gibbons kiln the fittings and miscellaneous can be fired in H-cassettes and U-cassettes
.
At a later stage Lafarge could consider optimising these kilns. At present, however, these kilns run different types of tiles. So optimising this could probably also result in higher output.

2.2.7 Logistic system

The present Lafarge site in Tegelen is an old plant of more than 140 years old.
This means that there are a large number of conveyer installations to bring the right tile to the right place. At the moment not very logic in terms of logistic efficiency, reason to look for a more suitable system than Lafarge Tegelen has at the moment.

Getting more and more insight and control over the total process of tile production typical illogic production facts pop up. An example is the fact that the miscellaneous tiles are not also being fired in the same kiln.

This means that we also can look whether changes in the logistics can also lead to higher output.
However in outlines the system is fixed; the large number of normal tiles have to be fired in the Lingl kilns as well as the verges, the eave-tiles and double roll tiles. Ridges can be fired at both type of kilns because of the fact they can be fired in U-cassettes, a small degree of shallowness within this tile is no problem.
Nowadays the Gibbons cannot handle H-cassettes, so when a kiln overhaul should take place an adaptation can be made to overcome this problem.

Figure 2.2 double H-cassette for TdN & Boulet-tile

Investigating the Tuile du Nord and the Boulet tiles shows us that we can put them, 2 in one, in newly designed, H-cassettes. This will result in a major quality improvement and also allows them to be fired in the Lingl kiln. It means, they have twice as many tiles on one kiln car, ergo more tiles by using the same pushing rate.

In this scenario, we would need to buy new refractory for the TdN-tile and the Boulet-tile. As mentioned several times above, wherever possible the use of H-cassettes would provide the level of quality, consumers desire. A prototype we constructed shows that in one cassette, two tiles can be carried which would mean very high efficiency.
First of all, a more favorable ratio of tile weight to refractory weight, and secondly a reduced use of kiln cars, which leaves more cars disposable for the rest of the production process.

2.3 Concept generation

The actual generation of concepts is classified into two groups: intuitive and directed. In practice often a combination of both methods is used. Intuitive concept generation methods focus on generating ideas from individuals or groups. The intent is to promote divergent thinking and creativity. Directed concept generation uses a systematic approach to searching for a solution. Solutions to technical problems are obtained through technical information, expertise and guidelines. The path for how to find solutions is determined, while the solution itself is not obvious at the beginning of the path.

This is a brief description of concept generation.

Now that we know the expected number of products per kiln car (see Appendix XII), we can make an estimate about the number of kiln cars per week, depending on the expected volume of 2008.

The complete information is listed in Appendix XIV.
Here we see the total amount of products, the type of press, which produces them, the number per shift and the number per kiln car. In this matrix we calculate the number of kiln cars per product per year.
By dividing the amount of tiles per year by the amount of tiles per kiln car we get the amount of kiln cars per year.
Table 2.2 gives an overview of the expected kiln cars for the new Gibbons kiln.

VH,OVH,NH,??	number kiln cars
Gevelpannen	2987
Vorsten	4842
Dubbelwel	306
Onderpannen	84
2/3 onderpan	78
Ventilatiepannen	49
Vorstgevelpan	121
Beginvorsten	101
Ballonvorst	36
Broekstukken	115
Broekstuk L+R	6
Zadelvorsten	18
Gevelonderpannen	9
Chaperonpannen	94
Chaperongevel	3
Knikpannen	31
Gevelpan Tesl.	132
Gevelpan Kruispan	12
Halvepan-L/R kr	32
Halve gevel kr	22
Chapperon Tesl	8
Chapperongevel Tesl	1
Knikpan Tesl	34
Knikpan kr	15
holle vorst	21
Totaal	9157

Table 2.2 overview expected kiln cars

We assume a kiln production time of 49 week, 7 days a week. This results in a pushing rate of 27 kiln cars per day.

In terms of an overhaul or revision of the Gibbons kiln we have several options,
Re-locating the fittings to the Gibbons kiln would increase the capacity of the Lingl kiln, as kiln cars are freed up for normal tiles. Moreover the process of firing could probably be upgraded, as only one type of tile would be coming through.
Moving the TdN-tile and the Boulet-tile to the Lingl would increase the capacity per kiln car.
A rough guess could give the following options:

Option 1: all the fittings to the Gibbons, TdN-tile and Boulet-tile to the Lingl kiln under use of a new developed double H-cassette.

Option 2: all the fittings + TdN-tile + Boulet-tile to the Gibbons kiln.

Option 3: option 2 + more fitting as a result of 15% more tiles in the Lingl kilns.

These options result in the next pushing rates for the new Gibbons kiln:

Ad1): 9157 kiln cars / year + 10% surplus -> **pushing rate 29,4 kiln cars per day**
Ad 2): 9157 kiln cars / year + 2865 kiln cars / year (TdN + Boulet) + 10% surplus -> **pushing rate 38,6 kiln cars per day**
Ad 3): 9157 kiln cars / year + 2865 kiln cars / year (TdN + Boulet) + 15% extra cap. + 10% surplus -> **pushing rate 44,4 kiln cars per day**

These rough concepts need to be further investigated whether they can be achieved by production and they have to be related to financial figures, to enable the management team to make a well founded choice.
In the next chapter the possible options will be drawn in a morphological scheme.

2.4 Morphological analysis

Morphological analysis

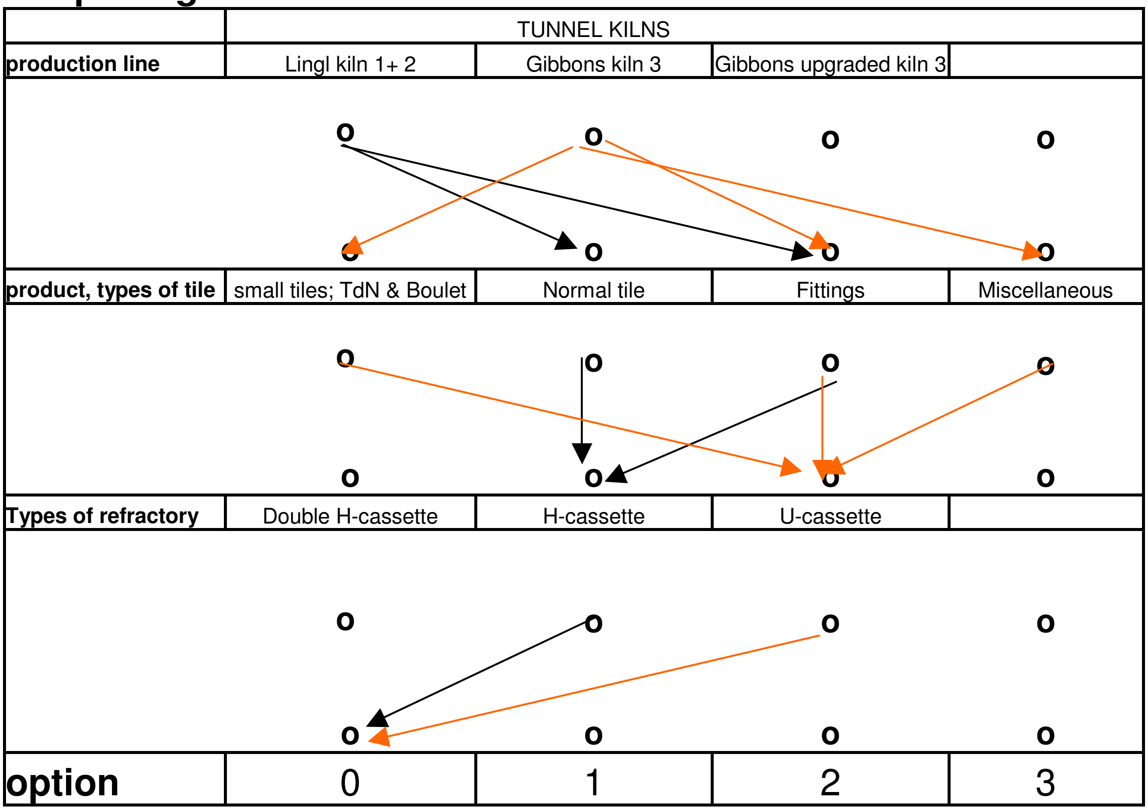
Morphological analysis is the process of creating product concepts from solutions for different product functions. An important aspect of this analysis is to make the final product less complex and less expensive by combining functions in product parts.

Product concepts are in principle the same as process concepts when you describe the process steps in the same way as you describe product parts or product functions. Enough reason to adapt this Van de Krooneberg method and apply it for production process concept generation

The variable items for this morphological scheme are the kilns, the type of tiles and the refractory. With these ingredients we have constructed this scheme.
By drawing lines from “a” to “b” we can visualise the possible options.

In figure 2.3 the morphological scheme of the present situation is drawn.
The other options are added in Appendix XV

Morphological scheme



When observing the 4 options, whereas:

option 0; is the present situation
option 1; all the fittings to the Gibbons, TdN-tile and Boulet-tile to the Lingl kiln under use of a new developed double H-cassette.
option 2; all the fittings + TdN-tile + Boulet-tile to the Gibbons kiln
option 3; is the present situation, although more fittings to the old Gibbons kiln and the TdN –tile + Boulet-tile on double H-cassettes to the old Gibbons, due to quality aspects.

With this method we can draw several possible options, however as there is a split off in a product and partitioning can vary, than this can only by figured and not drawn.

2.5 Conclusion data collection phase

At the start of the process of gathering data it looked very difficult to get a clear overview of all the necessary information. Now that everything is organized the data are easily accessible for use in the Research / Analyses phase, described in chapter 4.

3 Tunnel kiln

3.1 Introduction into the Tunnel Kiln

In the next chapter we will show what is possible with a tunnel kiln to its layout and its firing curve. We will explain, in a nutshell, how things work. This information is compiled in cooperation with our Process Engineer of Lafarge Technical Center (Crawley U.K.) Mr. Ir. I.C. Lenoir.
In the following sections we also look for an answer to the question as to whether our present Gibbons kiln would have the capability of a higher production output.

3.2 Operation of a kiln for clay roofing tiles

Clay roof tiles are fired in a continuous process. The standard kiln used for such a process is a tunnel kiln. The first section of the kiln is the heating up section. Further on, in the middle, the main firing zone is located. The last section is the cooling section. A cross section of such a kiln is presented below:

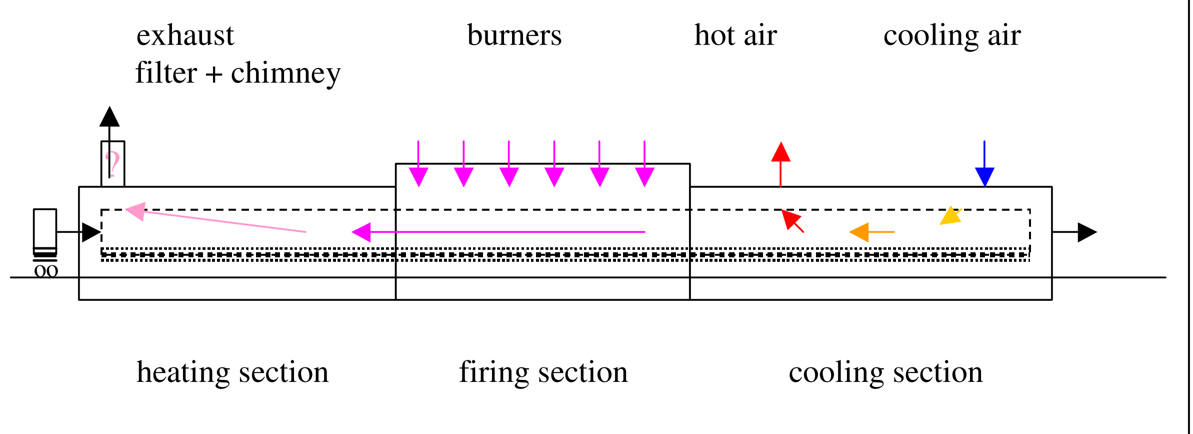


Fig. 3.1 cross section of a tunnel kiln

For the processing of the product it is common practice to distinguish different phases:

Phase 1 Post drying {first part heating up section}

The rest heat of the kilns preheats the already dried tile. In the entrance of the kiln, the product is heated quite quickly up to around 250°C. The residual moisture is now completely removed, to avoid the product exploding. This phase takes approximately ¾ of an hour.

Phase 2 Pre heating {second part heating up section}

Heating the product from completely dry to the top fire temperature is called the preheating phase. The chemically bound water from the clay disappears and organic material, such as humus, is burned out. Within the material a lot of mechanical stress (tension) is build up by temperature differences and shrinkage because of a change in morphology of the body.

Phase 3 Top firing

In this section burners are placed, between the stacks of tiles, to provide the necessary heat. See figure 3.2.
Every time when the kiln cars are pushed forward, the burners stop and when the kiln cars have reached there new position the burners start again.
To get a strong ceramic body the grains of 'clay' should be sintered. This means that the grain surfaces should melt together and a small amount of glass phase will be formed. This process results in a linear shrinkage of the product of approximately 1%. The processing time for this phase depends on time and temperature.
The higher the top temperature, the shorter the time for achieving this 1 % shrinkage. As always there are limits to be taken into account.

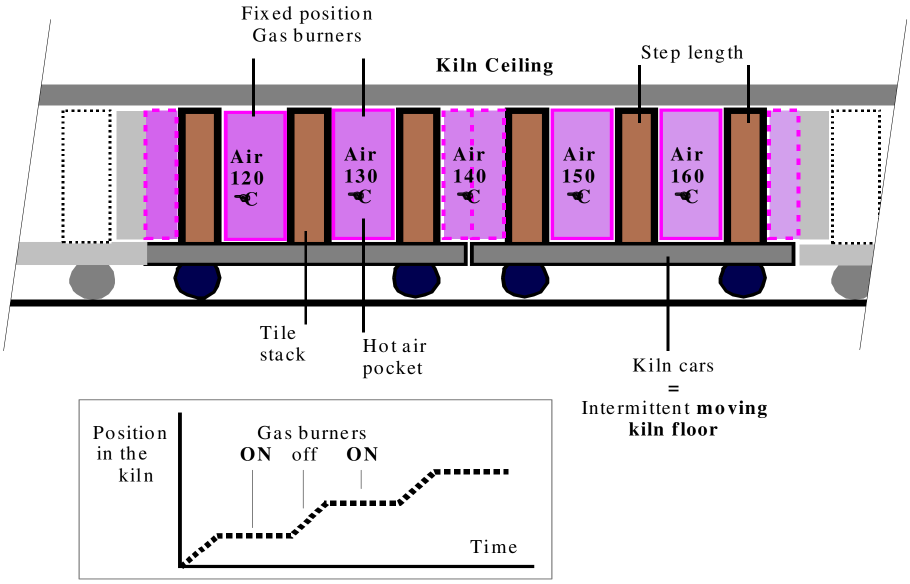


Fig. 3.2 Overview of the firing section

Phase 4 Cooling

Once the sintering process is completed, the ceramic body should be cooled down to a normal temperature of about 50°C. In an industrial kiln one should always try to speed up this process as much as possible. Cooling down a ceramic body from top temperature to about 50°C is critical during the quartz inversion. During this phase the quartz will be transformed from α-quartz to β-quartz at a temperature of 573°C. These two crystal structures have different volumes. During this conversion quartz particles shrink much more than the rest of the body. At this stage the product is susceptible to cracking. For Dutch clay-blends a cooling speed of about 40 to 60°C/h, during half an hour is acceptable.

Above and below the quartz inversion the speed of cooling has an almost uncritical behaviour. Therefore the cooling section of a tunnel kiln is technically split up into three subsections:

- Fast cooling from top temperature (cooling down to app. 225^{o}C/h)
- Quartz inversion section (cooling down to app. 50^{o}C/h)
- End cooling (cooling down to app. 165^{o}C/h)

The temperatures are taken from our 2 Lingl kilns, belonging to the clay blend of Lafarge Tegelen.

3.3 Construction of the kiln

A tunnel kiln has a main structure of refractory. The moving kiln cars create the bottom of the tunnel. Burners are located on the side of the walls (side burners) and / or in the roof (top burners). Fans are used to move the cooling air and the exhaust gasses through the tunnel. The basic fans are: cooling air fans, hot air fans, combustion air fans and exhaust fans. Modern kilns also use equipment to re-circulate air within a certain section of the kiln.

3.4 Production capacity of a tunnel kiln

The production capacity P of a tunnel kiln is determined by the pushing rate p. In practice the pushing rate is defined as the number of kiln cars per 24 hours.
As an assumption, the Gibbons kiln will have less capacity than the Lingl kilns.
This means in practical terms that examining the Lingl kilns will give us some useful figures, which can be extrapolated to the Gibbons kiln.

The actual temperature curve inside the Lingl kiln is shown in Appendix VII

Fig 3.2 shows the same temperature curve, however in this graph the temperature gradient is added as function of time.
This temperature gradient is obtained by calculating the slope angle of the temperature curve.
This is defined as the maximum temperature difference per hour over a straight temperature line of the curve. To determine this, the original temperature curve is divided into 14 parts.
With these figures we can construct our own temperature curve, with these gradients we know that the tiles do not crack.

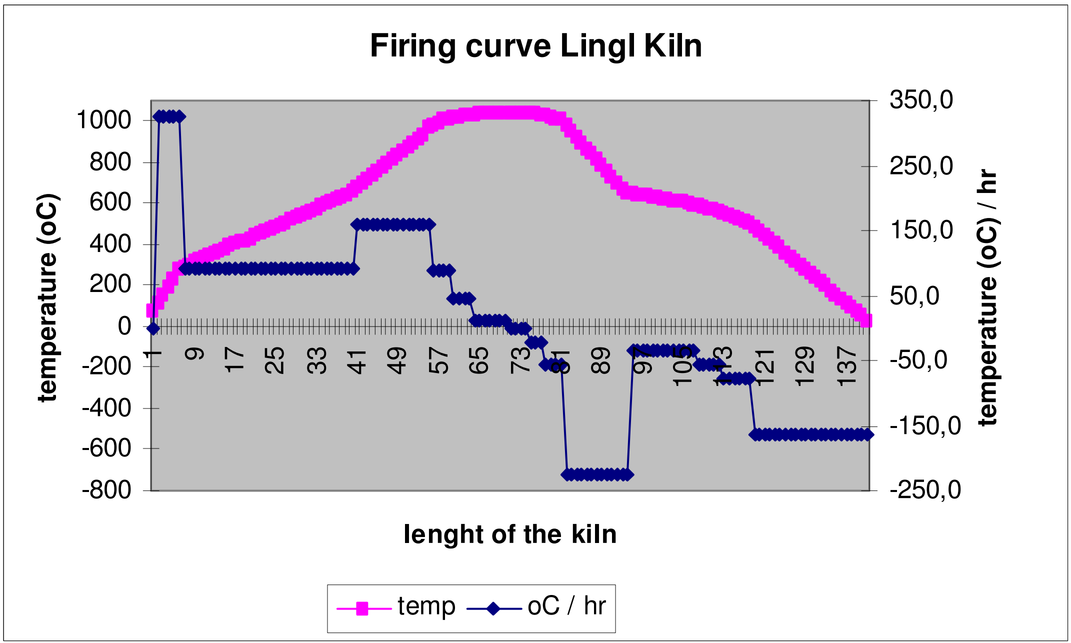


Fig. 3.2. Firing curve Lingl Kiln by a pushing rate of 70 kiln cars per day

These figures represent a pushing rate of 70 kiln cars per 24 hours. What means that the time that 1 car stays inside the kiln is 17 hours en 28 minutes.

As we know the weight / structure of the kiln we can say something about the power of the kiln.
A car contains 480 tiles + refractory.
Weight of the tile is app. 3.4 kg the cassette 3.8 kg, al together 3,456 kg/car.
Car (length * width): 2.70 * 4.00 = 10.8 m^2
Height over cars: 1.52 m → Volume of 16.416 m^3 for 480 cassettes / 1 car

For the existing Lingl kilns the setting S can be calculated:

→ S = 3,456 kg / 16.416 m3 = 210 kg/m^3

This, at least, could be also the setting in the Gibbons kiln.

The dimensions of a tunnel kiln are determined by:

1. The setting S of the product: kg product per m^3 kiln volume.
2. The allowable heating or cooling speed in ^oC/h in combination with the pushing rate gives us the length of the kiln section (see firing curve)

Ad 1.) For the expected Gibbons kiln car we assume:
Car (length * width): 2.62 * 2.38 = 6.24 m^2
Height over cars: 1.52 m → Volume of 9.48 m^3 for:

288 cassettes	tile weight: 3.4 kg	refractory weight: 3.8 kg
180 ridges	tile weight: 6.0 kg	refractory weight: 6.0 kg
144 verges	tile weight: 7.5 kg	refractory weight: 8.0 kg

For the new Gibbons kiln the setting S could be:

→ S tile = 2,074 kg / 9.48 m3 = 218 kg/m^3
→ S ridge = 2,160 kg / 9.48 m3 = 227 kg/m^3
→ S verges = 2,232 kg / 9.48 m3 = 235 kg/m^3

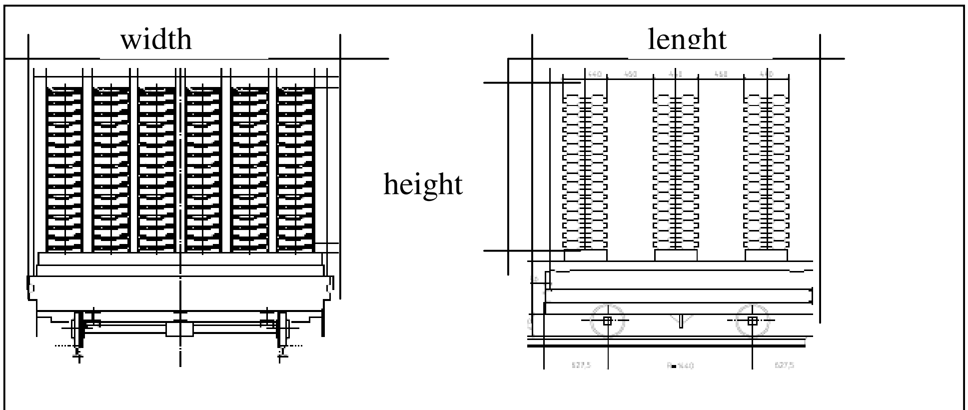


Fig. 8.3.2 Skits of a kiln car

Generally seen the S for tiles is the same as in the Lingl kiln, which means that it is technically feasible.
For the ridges and verges tiles there is a difference of about 20 kg / m3 which is approximately 10% more product.
This needs to be calculated by the kiln manufacturer, whether larger burners can compensate this. However the first gain is hidden in the pushing rate, the time that the tiles stay in the Gibbons kiln is longer than in the Lingl kiln. Therefore more energy is put into the mass.

Ad 2.) The temperature curve of the Lingl kiln is translated into heating and cooling gradients. These gradients are interpolated to the length of the Gibbons kiln.
Within these gradients it is possible to have a sufficient pushing rate, without enlarging the kiln.
Constructing this graph is done by keeping the heating gradient steady till we have reached the temperature from whereon the new heating gradient counts.

The data for this is shown in Appendix XIII. This curve is constructed by trial and error.

When firing tiles it is important that the tiles are equally heated. Not too fast so they would crack and not to slow, because this is too expensive.
The heating or cooling gradient is the amount of degrees per hour which, in this case, the Lafarge tiles in Tegelen can handle.
Knowing this from the fast moving Lingl kiln, we must technically be able to modify the Gibbons kiln the same way.
The pushing rate of the Lingl kiln is maximum 75 kiln cars per 24 hours; one car stays about 1048 minutes inside the kiln with a length of 140 m
As mentioned in ad1) we have a setting of about 10% more. Save suggestion, enlarge the firing time by 10%. Therefore 1152 minutes.

In the aforementioned Appendix XIII we put in the temperature gradient and we modeled the same firing curve as within the Lingl kiln. The conclusion of this all is that within the length of the present kiln we can theoretically achieve a pushing rate of 50 kiln cars per day.

Theoretical pushing rate approach.

Besides the trial and error method we determined a theoretical model of the pushing rate.

$$\frac{\Delta T}{\Delta t} = \frac{\Delta T}{\Delta x} \bullet V_{\text{kiln car}}$$

This can be seen in Appendix XXVIII, the result is 52 kiln cars per day, as where the trial and error gave app. 50 kiln cars per day.

3.5 Conclusion about kiln capacity Gibbons kiln.

Determining the pushing rate on 2 different ways and getting the same result we may conclude that an approximate kiln capacity can be achieved of about 50 kiln cars per day, without enlarging the kiln. This is about 3 times the present pushing rate.
However we have to rearrange the burners and perhaps increase their heat production capacity, but the length of the kiln is sufficient. This means that only the ceiling and partly the walls of the kiln have to be replaced. Hereby the boundaries / assumptions (see 1.4.5) that we can keep our present kiln rails, kiln cars and kiln foundation is being proven.

4 Research / Analyze phase

4.1 Introduction of the analyze phase

In the chapters above the necessary data for further analysis has been produced. In this chapter we will investigate and analyze the different items / options, which can then be set against each other comparing their positive and negative points, so we can combine several concepts.
The answers given here should cover our primary thesis research questions.

- What would be the best combination of tile production in Tegelen? I.e. what tiles should be produced in what kiln at what refractory
- What kind of kiln would they require or what adaptations have to be made?

In chapter 5 we will present the financial analysis of the project.

- What would be the cost of the proposed modification?
- Estimates of CAPEX and OPEX.
- What would be the Return On Investment (ROI)?

In the next sections we also explain the change in assumptions we made in September 2006. The world keeps evolving, so does Lafarge.

4.2 Estimated technical feasibilities

Estimating technical feasibility

Design evaluations take a lot of time. The design concepts that are not technically feasible should be excluded from the concept selection process. The estimation of the technical feasibility of a new concept must be carried out as the first step in the concept selection process. The same approach counts for new tile production process design

In these sections we will discuss the same subjects as already used in the data collection phase chapter 2.2.

- Amount of tiles which have to be produced (2.2.1)
- Production capacity (2.2.2)
- Kiln structure / dimensions (2.2.3)
- Kiln firing process (2.2.4)
- Types of refractory (2.2.5)
- Type of tiles (2.2.6)
- Logistic system (2.2.7)

4.2.1 Analyses of aspects related to the number of tiles to be produced

The main tile volume is estimated at 23 million tiles.

The data listed in Appendix V gives a cumulated overview of the production ratios from 2004, 2005 and partly 2006.
All the different types of tiles, fittings and miscellaneous are counted per type.
We have the amount that are pressed and the amount that are fired from the SAP management system. The difference between them is crack or blast.
We also know the amount of normal tiles produced in that year.
Dividing the amount of e.g. left hand cloak verges to the amounts of normal tiles, gives us the percentage of these fittings.
This gives us insight how many fittings and miscellaneous tiles are necessary alongside the main tiles.

The **cumulated data** gives roughly the following overview:

The ratio of cloak verges to tiles is approximately 1% [green section].
The crack or blast ratio of main tiles is approximately 3% [red section]
The crack or blast ratio to cloak verges is approximately 10% [purple section]

These ratios are necessary to make an estimate, further on, about how many tiles per type we need.

Some points must be taken into account:
The new type of tile, NH-tile, has the same crack percentage in normal tiles (is already very low, Tegelen won the "lowest scrap award" in 2003 of Lafarge Roofing world wide, was nominated for the award again for 2006, and won in May 2007) and a significant lower scrap ratio for the verges. This is due to the fact that these new fittings are better designed than the older ones.

In 2008 the "Re"- tile will almost certain disappear and be replaced by a new model. Nowadays the Re-tile is sold a lot in Germany, where more verges are used. The NH-tile is sold a lot in Scandinavia where they use fewer verges but more double-roll tiles.

A quick count shows that 0.1% more verges at 5 million tiles means 5,000 verges. This can be produced in about a 1 to 1.5 shift of production. Ergo a small difference can be easily compensated over the year.

The above suggests the aforementioned ratios are adequate figures for a production estimate.

When the new tile is introduced the large Roman-tile will also disappear. The small Roman-tile is no longer actively produced; only fittings for selling the remaining stock.

4.2.2 Analyses of aspects related to production capacity

The TdN-tile and the Boulet-tile are small, older types of tiles, mostly used for renovation.
Whether we are going to produce them in the Lingl kilns will depend on a calculation later presented below.

In Appendix IX we show an arithmetic exercise of what kiln capacity can be freed up in the Lingl kilns when fittings or TdN-tile and the Boulet-tile are produced in the Gibbons kiln respectively the Lingl kiln. Here we clearly see that by using either option we produce enough tiles to meet the expected demand (> 23 million).

			pushing rate	
			70	75
option 0	present situation	normal tiles	20.5 mil.	21.9 mil.
option 1	fittings -> Gibbons; TdN -> Lingl	normal tiles	22.0 mil.	23.6 mil.
		TdN & Boulet tiles	1.6 mil.	1.6 mil.
option 2	only normal tiles to Lingl fittings + TdN & Boulet to Gibbons	normal tiles	22.8 mil.	24.4 mil.

+/+ 7.8%

+/+ 11.4%

Table 4.1, Overview maximum output Lingl kilns

During the course of this project, there have been major developments that have changed the basic assumptions we have used.

First of all the maximum pushing rate of the Lingl kilns has been upgraded to 75 kiln cars per day per kiln.

This is a result of TPM {Total Productive Maintenance} and SGA {Small Group Activities} which stimulates us to continuously improve our production process

[12] see bibliography.

A pushing rate of 75 kiln cars per day means that within the present production schedule of 18 hours a day, we have to obtain an efficiency of 98% to get the full kiln capacity; this is not very realistic (nowadays 76%).
More production / press time means more shifts and therefore more people.
We are now running with three teams, the next option will be four or even five teams, because of the legally allowed schedule we are not allowed to overwork.
Every team is a group of nine people; whether this is a valid solution is calculated further on.
In case of no extra shift, we have to fire other tiles in these Lingl kilns to get the maximum output.
For this reason the TdN-tile and the Boulet-tile would probably have to be produced in these Lingl kilns as well as the “eaves” tiles and “double roll” tiles.
All of them are already fired in the Lingl kilns on a standard H-cassette.

The second point is that at the moment we are analyzing the possibility to start production of fittings for the Scandinavian markets. They produce the normal tiles themselves and want to purchase the fittings from Lafarge Tegelen.

The third option is to produce even bigger tiles than we are currently producing.
This affects the refractory in the newly to be designed Gibbons kiln; larger refractory, perhaps larger kiln cars and other modifications.
Within the scope of this thesis project, this option is not considered, because Lafarge Dakproducten Benelux made clear that this is no option for them at all.

An important final point is that we officially have been sold (65% of the shares) to PAI investment on March 31st 2007. At this time they require a return on investment of less than 3 years. A very short pay back time for investments as large as this are difficult to achieve.

Production quantities

The maximum kiln capacity of the Lingl kilns is 52,500 kiln cars / year.
{50 weeks x 75 kiln cars / day x 7 days x 2 kilns}

The production of the Lingl line is approximately 43,092 kiln cars / year.
{50 weeks x 7 days x 18 hours x 60 min. x 72 tiles per min x 76% eff. / 480 tiles per kiln car}

The production of TdN-tile and Boulet-tile is approximately 1,719 kiln cars per year.
{1,650,000 tiles / 960 tiles per kiln car}

This leaves 7,689 kiln cars capacity unused.

Optimizing these Lingl kilns means also firing the “eaves tile” and the “double roll tile” here. As these are already fired here, the installation does not need adaptations.
Firing one type of tiles (due to their lay-out) is good for the effectiveness of the kiln;
A lot of different types of tiles create a non-consistent airflow inside the kiln; this is less good than a steady airflow. Turbulence makes that a different heat exchange takes place. This affects the color of the tiles, which is not acceptable.
Besides this it is likely that different tiles of different types are different in thickness, which means that theoretically tiles need a different firing time. So optimizing the process by reducing the types of tiles in one kiln means that we probably also can optimize the pushing rate.
This is an option for the future and cannot be carried out at this moment.

Appendix XIV shows the expected amount of fitting, belonging to 23 million tiles (already explained in section 2.3). Here we use the specific ratios as described in section 4.2.1; multiplying these with the expected amount of normal tiles gives the amount of fittings and miscellaneous:

Eaves tiles :	24 K tiles / year
Double roll :	88 K tiles / year
2/3 eaves tiles :	22 K tiles / year
These tiles need about:	134 K tile / 480 tiles per kiln car = 280 kiln cars a year.

By producing these tiles in the Lingl kiln, we still have plenty room for an expansion in production capacity.

The rest of the tiles, mentioned in Appendix XIV, need to be produced in the Gibbons kiln. This assumption is necessary to get the highest output in the Lingl kilns.

The new Gibbons kiln needs to produce 26 kiln cars per day, without 10% unforeseen. Comparing this with its present pushing rate from 14 till 20 cars / day, makes it clear that some major changes have to be made here.

4.2.3 Analyses of aspects related to the kiln

According to the collected data, tiles must be put into the right refractory. This is a basic quality requirement. To minimize costs, we must determine the optimal arrangement of the kiln cars. This is also necessary to determine the capacity per kiln car. It affects the pushing rate as well as the buffer capacity of the rails.

The refractory / tile stack layout and configuration determines the position of the gas burners, along the kiln wall and ceiling. The train of kiln cars moves forward one position at the time. Then rest in place for a specific amount of time and then moves forward to the next position. At rest the burners must be in place then between the tile stacks in order to achieve the best heat exchange without burning the tiles. If the latter were to occur, the tiles would crack or get torched.

Given its age, it is clear that the present controlling system is not "state of the art", and above all its safety system is not fail-safe.
Reason to replace it when upgrading this kiln.

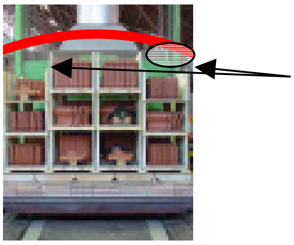


Figure 4.2
View of an arch

As already mentioned before this Gibbons kiln has an arch ceiling, which creates, together with the u-cassettes, a lot of unused space. To get a system with greater control it is preferable to replace this ceiling by a flat ceiling. This would also result in a higher filling effectiveness of the kiln.

In light of the above, and in conjunction with 1.4.5, the kiln can be rehabilitated with only few adaptations.

As explained in chapter 3, we examined the heating curve of the Lingl kilns.
When using the information of the maximum heating gradient, X ^{o}C / hour, we can easily extrapolate this data into a kiln of 100 meters, with the result: a maximum pushing rate.

The aforementioned is showed in Appendix XIII. Here we put in the temperature gradient and we modeled (by trial and error) the same firing curve as within the Lingl kiln. The conclusion of this all is that within the length of the present kiln we can theoretically achieve a pushing rate of 50 kiln cars per day.
This means that the 26 cars of section 4.2.2 can easily be achieved.

A more theoretical analysis gives a pushing rate of 52 kiln cars per day and can be seen in appendix XXVIII.

4.2.4 Analyses of aspects related to Refractory choice

Kiln car refractory cladding

In terms of the refractory, nowadays the heat transmission rate (insulation value) of the new refractory bricks, that cover the kiln cars, is much better than it used to be. To try and determine whether it would be useful to replace the refractory, we consider a very recent report produced by Dr. David Howling in April of this year.
He examined the 2 Lingl kilns, in table 2a and 2b of Appendix XVII an energy balance is shown, which reveals that. The kiln cars absorb about 500 kW of a total of 3,600 kW.

For the purpose of this case we assume that the new refractory saves 50% on energy.
The cost price structure (copied out of the SAP system of Lafarge) of main tiles without glaze (ergo: RED tile) shows that the gas consumption of the Lingl kilns is about 168 m3 gas / 1,000 tiles which is about € 44.
In Appendix XVIII the complete cost structure of 3 tiles is shown. In the red box at sheet 2, you can find the gas consumption of the kiln.

The estimated 50% of energy saved, amounts to some 250 kW, which means 6.9% of the total fuel consumption.
This is about € 3.00 per 1,000 tiles. The new Gibbons kiln produces about 1.5 million tiles this gives us (very rough calculation) a profit of € 4,500. This cost saving would not even be sufficient to renew 1 kiln car. Refractory cladding for one car in December 2006 costs about € 6,000 and we have 100 kiln cars. Given these financial results, the assumption of a reduction in energy consumption of 50% does not affect the outcome of the example at all.

Refractory TdN-tile and the Boulet-tile

For the TdN-tile and the Boulet-tile we need to buy new refractory.
As mentioned several times above, wherever possible the use of H-cassettes would provide the level of quality that consumers desire. A prototype we constructed shows that at one cassette, two tiles can be carried. This means a very high efficiency.
First of all, a more favorable ratio of tile weight and refractory weight, and secondly a reduced use of kiln cars, which leaves more cars for the rest of the production process.
The cost of the new refractory support is about € 17.50.
In 4.2.2 we see that we need about 1,719 cars per year, which means at a production of 5 days a week, 49 weeks a year about 7 cars per day. Including some spare supports, we need about 3,750 supports, => € 65,625.
The rest of the refractory, for ridges and verges, can be re-used in the Gibbons kiln, requiring no additional investment.

If however we do not transfer the TdN-tile and the Boulet-tile to the Lingl line, than with respect to the costs (cassettes + the necessary (un)loading equipment) we suppose that these tiles will still be fired in the U-cassettes.

4.2.5 Analyses of aspects related to Logistic system

Now that, during this thesis project, the pushing rate of the Lingl kiln has been increased it is possible to fire more tiles without re-arranging the process. This is perhaps not a nice option, but within respect to the thesis question (roughly put): more tiles lower costs. It is worthwhile financially investigating this as well.

4.3 Concept selection

Two definitions of concept selection are quoted; they do not differ a lot from each other.

Concept selection

During the concept selection process important decisions for the development project are made. Basically two steps must be carried out. Care must be taken that all good ideas are selected and that all relevant selection criteria are -taken into account

Concept selection

During concept selection important choices for the progress of the development project are made. The aim is to reach consensus within the development team. If no consensus can be reached, then the reason why must be clear and the necessary step to solve differences of opinions must be determined. Important aspects of concept selection are defining selection criteria, ranking the concepts, evaluating the concepts and attack the negatives of selected concepts.

The concepts, which are selected, differ in terms of quantity of products and in which kiln they are going to be produced. The selection criteria are simply the financial consequences of the different options.

The basic assumption is the sales forecast of 23 million roof tiles in 2008 and beyond. Now that the Lingl kilns can fire with a pushing rate of 75 kiln cars per day, we can reach this expected sales level. However in the present 3-shift production system we cannot reach the expected number of tiles. This leads us to two basic possibilities;
a) going to a 4-shift system or
b) stabilize the quantity to the present 21 million roof tiles.

Regarding option b there has to be no change of the present process.

Because option b is the present situation, we do not have to undertake a financial analysis. We are now going to determine what possible options there are with option a.
Financial results within these options will then give positive or negative result with respect to the present situation.

Starting a 4-shift system results in an increased production output level.
The morphological options are arithmetically worked out in Appendix XXVII; here we see the number of expected tiles per option. Also a split off is made with ridges, this is actually the case between the fittings- and Gibbons line.

Within a 4-shift option we can produce more than the desired 23 million tiles. This means that we can optimize the system by increasing the output to the maximum, which results in a higher efficiency level.
With the increase of tiles, the fittings and miscellaneous products will have to increase too.

	possible combinations			theor number	reduced kiln	pushing rate	expected reduced
	Lingl kiln	Gibbons Kiln old	Gibbons kiln new	kiln cars lingl	cars lingl	Gibbons	production volume
option 0	a+b+50% c+d+e+f+g	50% c + h		55846	52500	17	23459970
option 1	a+h		b+c+d+e+f+g	53708	52500	24	24375000
option 2	a		b+c+d+e+f+g+h		52500	35	25200000
option 3	a+b+d+e+f+g	c + h		54270	52500	21	24141154
option 4	a+d+e+f+g		b+c+h	52326	52326	33	24955000

Table 4.2 overview of expected production volumes per option.

Option 0: This is going to be the situation when production goes to 4 shifts.

Option 1: all the fittings to the Gibbons, TdN-tile and Boulet-tile to the Lingl kiln under use of a new developed double H-cassette.
Here we see 24.4 million tiles + 1.65 million TdN / Boulet tiles and the new Gibbons has a pushing rate of 24 kiln cars per day without miscellaneous.

Option 2: all the fittings + TdN-tile + Boulet-tile to the Gibbons kiln.
In this option the Lingl line cannot produce enough tiles to what the kiln can handle, therefore this option **is not valid.**

Option 3: No new Gibbons kiln + all the ridges to the Gibbons, here we notice that the pushing rate of the old Gibbons is too high; therefore this option **is not valid**. Producing less ridges means producing a little bit at a different place; this affects us a too large logistic problem.

Option 4: Some fittings to the lingl line, the ridges and verges and the TdN / Boulet-tile to the new Gibbons. This option is valid and delivers about the same amount of tiles.

4.4 Conclusion analyze phase

To full fill the sales demand of 23 million tiles, Lafarge has to increase their production schedule from 3 to 4 shifts.
Whether this negative or positive affects the cost price of the tiles will be checked out in chapter 5.

Careful investigation and analyzing the gathered data, leads to three options for further examination;

Option 1: No extra investment, all the products stay in the Lingl kilns, only the amount of ridges in the Gibbons kiln increase and the TdN and the Boulet tiles stay here either.

Option 2: All the fittings and miscellaneous go to the new Gibbons kiln and the TdN and the Boulet tiles go to the Lingl kiln, this increases the total number of tiles in these kilns.

Option 3: The verges and ridges + de TdN and Boulet tiles go to the new Gibbons kiln. For this an investment would have to be made; however the Lingl output has increased.

In chapter 5 the full financial analyses of these three options will be explained.

5 Financial Analyses

In the following chapter some basic principles of business economics will be explained. The different options will be assessed against those principles, whereas we will explain in several sections what will change (financially) against the present situation.

5.1 Introduction into business economic principles

"Four out of five firms that went bankrupt were actually profitable;
they died from lack of cash, not from meagre profits".
(Quote from Hawawini and Vialet) [11]

The above quotation suggests, why a sound financial analysis of a possible overhaul of the Gibbons kiln is imperative.

Buying new equipment will be a major drain on our cash flow. A calculation of the positive and negative cash flows of such an investment would enable our financial department to take a well-founded decision as to whether to go ahead and buy.

5.2 OPEX

Operating Expenses are costs that incur as a direct result of manufacturing roof tiles. Those expenses recur every year and are needed to keep the plant going e.g. wages, clay costs, energy etc.

5.3 CAPEX

Capital Expenditure leads to the creation of assets, which add to the capacity of the system.
In basic terms this is the negative cash flow required to obtain the calculated OPEX and revenues.
The depreciation of this CAPEX is also required to get a good idea of the final return on investment.

5.4 Net Present Value

Taking into account a certain internal discount rate all the revenues and costs can be calculated towards time = 0, i.e. we will obtain the figures translated into "present" money {After all € 1,000 now is more money than € 1,000 in e.g. 2 years}.

5.5 Depreciated Cash Flow (DCF)

At Lafarge Roofing we use the so-called Discounted Cash Flow (DCF) system.
This means that we look at an investment at its start, time = 0, and we calculate the net present value of it's revenues, considering a certain discount rate, tax return and depreciation.

[11],[14] see bibliography

5.6 Financial Variables

5.6.1 Cost price reduction TdN / Boulet tile

Moving the TdN-tile and the Boulet-tile to the Lingl line would result in a reduction of the costs of the tiles, mostly owing to less manpower and cheaper kiln costs.
However, when the Gibbons will get a new kiln + loading equipment, its likely that the new production costs in this kiln will be about the same as within the Lingl kilns.
Also when the TdN and Boulet –tiles are fired in the Lingl kiln the cost are expected to be at the same level.
Therefore the cost structures of three representative tiles are taken from the SAP system.

- o TdN-tile red; this is the small tile from the Gibbons line with its specific costs.
- o The VH verge red; this is a fitting from the Lingl kiln and a semi automatic package
- o VH-tile red; as a fast mover in a complete automated production line.

By reshuffling this data and looking to what the probable cost will be in the new situation, based at my own competence in cooperation with Mr. Dipl. Ing. A. Laumans, we can make an estimate about the expected cost price.
The present cost price is € 1,239.93; the expected cost price is € 1,099.20.
At a production output of 1,65 million tiles this gives a positive result of € 232 K.

In Appendix XVIII the total cost allocation of 3 products can be seen {sheet 2,3 and 4}, as well as the composed cost structure of the "new" TdN & Boulet-tiles {sheet 1}.

5.6.2 Cost price reduction Gibbons production facilities

In terms of the new Gibbons kiln, it is difficult to say anything about the cost price, because we are dealing here with very different products and in very small numbers referring to the Lingl line.
However, by creating the new situation as mentioned in Appendix XIX (the proposal of the new kiln) we can forecast the FTE (Full Time Equivalent) reduction in Tegelen.

	present FTE's	FTE's with new system
presses	3	2
railcar	2	1
glaze	1	1
gypsum	2	1
loading / unloading	4	2
packaging	5	1
all-rounder	1	1
Team leader	1	0
	19	9
total reduction in FTE's		10

Table 5.1 overview FTE reduction by Gibbons Overhaul / renewal

An expected reduction of 10 FTE's means a reduction in labor costs of about € 40,000 per FTE = € 400,000. This gives additional payback.

Most probably the cost of the kiln will go down as well, but as already mentioned, it is difficult to determine how much, especially because the total quantity of tiles is low, compared with the Lingl kilns.

5.6.3 Extra production efficiency Lingl

Apart from the tiles referred to above, the Lingl kilns increase their capacity.
Just by introducing the 4th shift, they produce about 3,000,000 tiles more then before.
In the cost allocation data (out of SAP; Appendix XVIII- sheet 2), the production labor costs are showed in the yellow frames.

tile	subject	variable wages		time		description
vh rood	drying	€	30,52	0,625	min	dr6/4 pers
vh rood	drying	€	7,04	0,129	uur	teamleider lingl
vh rood	drying	€	20,27	0,448	uur	gips dr6/4
vh rood	drying	€	3,11	0,057	min	planning
vh rood	drying	€	1,04	1,164	min	kwaliteit
vh rood	drying	€	2,13	2,327	min	opleiding
vh rood	drying	€	1,64	1,78	min	kantine
vh rood	drying	€	2,13	2,327	min	logist prod
	sub total	€	67,88	per 1000 tiles dried.		
		€	69,24	from 1000 to 1020		
vh rood	firing	€	3,17	3,468	min	plann
vh rood	firing	€	1,09	1,179	min	kwal
vh rood	firing	€	2,13	2,357	min	opl
vh rood	firing	€	1,64	1,803	min	kantine
vh rood	firing	€	2,13	2,357	min	log prod
vh rood	firing	€	1,53	1,665	min	waterzuiv
vh rood	firing	€	7,15	7,835	min	teaml lingl
vh rood	firing	€	37,15	4,891	min	lingl oven
vh rood	firing	€	10,68	15,936	min	sort
vh rood	firing	€	8,93	15,936	min	verpakk
vh rood	firing	€	7,12	12,749	min	afvoer prod
	TOTAL	**€**	**151,96**	**variabel wages per 1000 tiles**		

Table 5.2 Overview variable wages of production people
For manufacturing tiles

The variable labor costs of the Lingl products are figured at about € 152 / 1000 tiles.

An extra shift consisting of 9 people, cost app. € 52,000 / year / man, which brings us to € 468 K per year. This related to 3 million tiles leads us to app. € 156 / 1000 tiles.

Moreover, sales gets an extra contribution margin of about € 300 per 1000 tiles.
Meaning € 1 million and the fixed costs will not increase.
Therefore the 4th shift is a good option.

The 3 options, which have to be examined, each result in even more tiles.

Option 1: + 0.5 million tiles; € 300 / 1000 tiles => + € 150 K
Option 2: + 1.4 million tiles; € 300 / 1000 tiles => + € 420 K
Option 3: + 2.0 million tiles; € 300 / 1000 tiles => + € 600 K

5.6.4 Production schedule

Producing tiles at this level means we have to determine what would be the most appropriate production schedule to be used.
Our tiles are produced at several presses, namely:

- 1 DR6/4 press (revolver press); Lingl line and therefore not part of this project.
- 3 DTP presses (turn table presses); 1 for de TdN-tile and 2 for de rest
- 1 semi automatic slide press; small quantities
- 2 hand slide presses; very small quantities

Within the 3 aforementioned options there is a restriction in the Gibbons production line. Although there has to come a new tile-loading unit, this unit can only handle one type of tile at the time. Ergo, they cannot load e.g. ridges and TdN simultaneous.
This means that producing all the fittings and TdN at this line, we have to work in more shifts.

Producing the current number of tiles in one shift has the preference over increasing the number of shifts, due to the much higher costs of labor involved in doing so. Having said that, flexibility and logistic simplicity is increased with more shifts. A higher production output would perhaps justify using 2 shifts, this should lower the production costs as fixed costs are spread over a much greater number of tiles. We have 2 presses but we press with one at the time as this enables us to change products at one press and because the kiln car loading system cannot handle 2 types of products simultaneously.

In the 3 options we calculate the differences between the options. Already counting that we are going to produce in 4 shifts. Reality tells us that in March 2008 we are speeding up to 4 shifts.

In Appendix XXV we give a quick calculation of the expected production time, per option.
Option 1: Lingl: no extra efforts Gibbons: no extra effort
Option 2: Lingl: no extra efforts Gibbons: 5 shifts, 9.5 hour per shift
Option 3: Lingl: no extra efforts Gibbons: 72 production hours per week

Whether we can actually produce the amounts in the expected time and have enough kiln cars available in the system, needs to be calculated too.
Appendix XVI shows a constructed production schedule {by trial and error} to see if we can handle this in the Gibbons production line.
Here we conclude that with a pushing rate of app. 27 kiln cars per day the system can role. This fits within option 2.

Option 3, analyzed according to the same structure as option 2, gives a pushing rate of 34 kiln cars per day, however in this case the Gibbons line needs to go to a 2-shift operation. Because of the more production hours, we did not make a production schedule to see whether we have enough available cars. When this can be done by few production days this is no problem by more production days.
However, because of the extra shift this means additional man-hour costs for 9 people, meaning € 360K.

5.6.5 Maintenance costs kiln

Our own technical department, supported by different third parties, heads maintenance. Within this budget we carry essential maintenance; preventive and corrective maintenance, including the legal inspections required.
A reduction in this budget would, a few years down the line, lead to more breakdowns ergo shorter meantime to failure and probably longer time to repair.
A general FMEA, for the complete production line, has been made. This to position our maintenance actions.
Here we see clearly that the kilns are our most critical parts of the system.
This can be checked in Appendix X.

To get a better knowledge about the critical items of the kiln system, a functional decomposition model of the kiln is designed. This is illustrated XXVI.

As there are already 3 kilns in use at the Tegelen plant; we have enough data about the exploitation costs. The functional decomposition of a tunnel kiln, shown in Appendix XXVI, is the red line of the maintenance needs, explained below.
The total costs of maintenance are divided to the different items.
In respect to maintenance we have made a functional decomposition of the kiln, however by further analyzing the project, this functional decomposition does not affect the answers to our thesis questions.

The subdivision of the kiln according to Appendix XXVI:

1. kiln frame work, bricks and refractory
2. kiln cars
3. rotating equipment like air fans
4. piping
5. heat exchangers
6. plc steering, frequency adjusters, wiring
7. switches
8. gas burners + piping
9. measuring equipment
10. kiln trolley + rails
11. chimney

A further brief explanation will show what kind of maintenance will be carried out and what the costs of this maintenance will be.

Ad 1) With our present kilns there have so far been no problems with the walls and ceiling. This is why we only instruct the kiln operator(s) to be alert when he is near the kiln, so that in case cracks occur he can call the maintenance manager to ask how to deal with the problem.

No action, no costs.

Ad 2) Kiln cars are steel frames with 4 wheels with roller bearings. The top of the car is equipped with cladding refractory which protects the steel frame. A labyrinth of refractory constructs the seals between wall and car. The cars are cooled underneath by an air fan and the heated air is being reused to pre heat the tiles.
Due to the cooling the bearings will get no hotter than 250^{o}C. The bearings are greased every 3 months to keep the kiln cars running smoothly.

The costs of this amount to some 24 effective hours of manpower + € 1,200 for special grease, every 3 months.

Ad 3) The fans attached to the kiln are quite simple devices, some of them directly driven some driven by V-belts. The directly driven fans are only greased twice a year by the kiln operator. The V-belt-driven fans are mostly used at higher temperatures and grease units automatically grease them. V-belts are replaced every three years. The most important fans are carried out redundantly for a steady firing process.
When no problems occur, the fans are dynamically balanced every 3 years

Annually framed costs amount to € 7,500.

Ad 4) the piping is placed indoors and normally fully insulated. Because the kilns do not stop there is no problem regarding moisture. The air inside is not aggressive, so no problems are expected.

No action, no costs.

Ad 5) The heat exchangers are regularly cleaned by the kiln operator. The temperature is constantly monitored, in case a deviation occurs the system gives a warning.
At the old Gibbons kiln the current heat exchangers have never been replaced.

No action, no costs.

Ad 6) Less preventive maintenance is carried out on the electrical components, such as plc and frequency adjusters. We are dealing here with constant failure behaviour. To reduce mean time to repair we make a system back up every time a programme change is made. Every 2 years we replace the back up battery for the RAM memory, and we keep the important components in stock.
Wiring is correctly mounted on rails, so no problems are expected.
The electrical system is annually checked by specialists within the scope of NEN 1010 and NEN 3140.

The costs of replacing batteries + making back ups are estimated at € 250 per year.
The electrical check up for this part of the plant is estimated at € 250 per year

Ad 7) Switches and relays at the cupboards are preventively replaced depending from the number of switch-activities. For this purpose the planner keeps a list and makes preventive orders to replace them. This data is collected through out the years, so we have a quit good sight at what needs to be replaced.

The replacement costs including materials are estimated at € 2,500 per year.

Ad 8) The gas system is being maintained first of all by our kiln operator. He replaces gas nozzles, pressure adjusters etc.
At the same time the system is checked annually by a specialist within the scope of legislation, so called SCIOS rules / instructions.

Costs of burners + miscellaneous amounts to some € 2,000 annually
The periodic inspection costs € 2,250 annually.

Ad 9) measuring equipment is fully monitored, so in case of, for example a cracked thermocouple, the system automatically gives an alarm.
Pressure boxes are annually adjusted + piping cleaned. This also is part of the job of the kiln operator.

Costs of equipment are estimated at € 4,000 annually.

Ad 10) The kiln trolley is a platform which pulls the kiln cars out of the kiln and places them on a buffer place. These trolleys are placed redundant: when one stops, the other takes over.
The drive is an electro motor, the rest are hydraulic systems. The cars are inspected annually and the hydraulic units get a check up. When leakages occur, the components are replaced. As there are several such trolleys at the site, cylinders, pumps etc. are kept in stock.

Annual costs are estimated at € 1,500 per trolley (4 per kiln; 2 at the front, 2 at the back).

Ad 11) In Tegelen there are two chimney's, one old chimney made of bricks and one alloy steel chimney.
The brick chimney is annually inspected by a specialist, at a cost of about € 800 per year.
Once every 10 years the chimney needs an overhaul; the investment costs are about € 30,000.
The alloy steel chimney is checked once every three years, at a cost of € 2,800.

A contraction of the preventive costs amounts to about € 35,000.
This is exclusive of overhead costs of team leader, planning etc.
After a financial check of the total costs, corrective maintenance is estimated at € 10,000 per year.
One kiln operator looks after three 3 kilns, during a day shift and this is not a full time job. Apart from looking after the kilns he works as a forklift driver for approximately 30% of his time.

These overhead costs are not calculated here, because they would not change as a result of a new kiln being installed.
The preventive and corrective costs of the old Gibbons kiln are about € 17.000 per year (Profit & Loss overview Tegelen 2004 until 2006; ! not included).

5.6.6 Investment costs

As we want to change the kiln, we also need to adapt the kiln car loading / unloading units.
Different types of tiles also require different machinery.
In light of this, we had requested a quote in June 2006, to see what the approximate costs of such a change would be.
Apart from this quote, other adaptations have to be made, such as the loading system of the TdN-tile and Boulet-tile at the fittings loading unit.

	Subject	mechanical	electrical	Total m+e
1	adaptation fittings laoding	€ 165.425	€ 53.000	€ 218.425
2	renewal kiln	€ 2.164.000	€ 1.134.200	€ 3.298.200
3	loading unit adaptation	€ 2.033.600	€ 675.680	€ 2.709.280
4	general	€ 380.000	€ 315.000	€ 695.000
	Total investment	€ 4.743.025	€ 2.177.880	**€ 6.920.905**

The offer of a kiln manufacturer is added in Appendix XIX.

In Appendix XX a rough cost overview of the entire overhaul is presented.
The total costs are presently framed at € 7 million.

5.6.7 Investment cost refractory

Options 2 and 3 would involve additional investment costs namely, to buy refractory for the TdN-tile and the Boulet-tile.

The cost of the new refractory supports is about € 17.50 each.
In 4.3 we see that we need about 1,719 cars per year, which means at a production of 5 days a week, 49 weeks a year about 7 cars per day. Including some spare supports, we need about 3,750 supports, => € 65,625.
The kiln cars mentioned here belong to option 2. However when firing the TdN and the Boulet-tile in the new Gibbons kiln, we need the same amount of refractory support; though they are divided between more kiln cars (Lingl: 480 pieces / car; Gibbons: 288 pieces / car).

The rest of the refractory, for ridges and verges, can be re-used in the Gibbons kiln, requiring no additional investment.

If, however, we were not to transfer the TdN-tile and the Boulet-tile to the Lingl line, with respect to the costs involved we could assume that these tiles would still be fired in the U-cassettes, however the extra investment costs of the adaptation for the TdN-tile and Boulet-tile are about 5% of the total investment and therefore this option is not calculated.

5.7 Calculations

The three options described in 4.4 are calculated according to the DCF system.
All the aforementioned amounts are used in these calculations.

In the calculations we used the common figures of Lafarge Roofing for the internal rate of return (13%) and the inflation correction (1.4%).
It seems quite clear that producing a much larger quantity of tiles at the Lingl kiln would be much more efficient than retaining three-shift production, see 5.6.3.
Because 4-shift is a good option without extra costs, this is taken as standard.
So the benefits of this option have no influence to this project.
The options calculate the (dis)-advantages of more production and or investments above the 4-shift system.

To see how sensitive the result of the calculations are for different assumptions, we do make a check up for the better and the worse.
Because option 2 gives the best results when renewing the Gibbons kiln, we re-calculate this option. {However, making more calculations would not be a problem.}
Within these calculations we change e.g. the CAPEX by + and - 10%, the revenues by + and - 10% and also the discount factor with –2%.

What becomes clear is that none of these alterations substantially improve the return on investment. See Appendix XXIII.

5.8 The unexpected

Besides the financial figures we are talking here about a kiln of an age of more than 40 years. This includes that technically seen this kiln is old fashion with its limitations of energy consumption, spare parts and safety. Because this kiln never stops, the present situation of its brickwork is hard to determine.

To see what a sudden disturbance would mean for Lafarge Tegelen, we make an assumption and introduce this in option 1 (the present situation; no extra investment). Just to see what happens.

Suppose that a part of the brickworks collapses. Then we have to cool down the kiln to repair it.
Cool down to work inside takes about 14 days, removing kiln cars takes 3days.
When the kiln is out of production, we have to repair also other disturbances inside.
Suppose 3 weeks overhaul. Starting the kiln for becoming the temperature profile inside the kiln we take 7 days.
Summarized: 6 weeks no production; 360,000 tiles, sales revenues € 300 / 1000 => € 1 million
19 people, 6 weeks, € 40,000 / year => € 90,000
3 weeks overhaul app. € 100,000
⇨ approximately € 1.2 million unforeseen costs.

In our calculations we assume these costs are coming after a) 2 years and b) 6 years. What becomes clear now is that when such an event occurs, the benefits of option 1; no investment, are melting away. However, the longer it takes before such event occurs, the better the benefits stay.

5.9 Conclusion DCF

After extensive research for figures and a great number of calculations, it becomes clear that the pay back time for a renewal of the Gibbons kiln is far more than 15 years. Mainly depending on the level of the investment and the discount factor etc.
However because of the age of the kiln an unexpected event may happen. This event can easily disturb our picture of the return on investment.

6 Conclusion

6.1 Summary

The basic question is how to produce more tiles in Tegelen at a lower cost price.
This question arises from the fact that old Gibbons kiln is over 40 years old and therefore not “state of the art”.

The intended outcome of this project is a performance plan that addresses some of the following questions:

- What would be the best combination of tile production in Tegelen? I.e. what tiles should be produced in what kiln at what refractory
- What type of kiln would they require?
- What would be the cost of the proposed modification?
- What would be the Return On Investment (ROI)?
- Estimates of CAPEX and OPEX.

After thorough research it seems clear that we should produce, as many tiles as possible, at H-cassettes. This is done to conform to current quality requirements in the market.
Investigation into the kiln cars leads us to the conclusion that an overhaul of these cars would be unnecessary and that renewing them would not provide any additional benefits.

Overhauling the Gibbons kiln would be a good alternative, but to put this into practice would mean having to keep the foundation and the walls as they are, and to put a new ceiling onto them as well as equipment with the latest control systems and piping etc.
The ceiling needs to be replaced because the present kiln has an arch ceiling by which the airflows are hard to control, as a result of the fairly big holes to the upper left and right of the cars. These holes are there because the ceiling is curved and the cassettes are straight.

The cost of the proposed modification is estimated at about € 7 million.

The main conclusion of this research project is that financially seen no reasonable pay back time can be achieved in case of an overhaul of the old Gibbons kiln.
The Lingl line has to introduce a fourth shift to be able to produce the expected amount of tiles, sales forecasts.

In the less worse option the Gibbons line would have to produce in two shifts to achieve the required level of output.
A sensitivity check shows that deviations in assumptions have little affect on the pay back time.

6.2 Recommendation

Overhauling the Gibbons kiln, as already explained above {6.1}, is financially not the best option for Lafarge Tegelen.
However, because of the age of the kiln it is likely that a crack of brickworks occurs.
A sudden disturbance in production, with its related costs, will change the picture of the efficiency of the investment.
Besides the analyzed consequences there are other aspects that count in an overhaul or replacement.
Those questions are for example:

- "How long will we keep this plant a live?"
- "What will be the reliability in the near future?"
- "How safe in this kiln?"

Ergo, there are more aspects than that we have researched and analysed.
Therefore it is up to the senior management to see what the strategic view is for Tegelen.
When the plant stays in business, an overhaul should be seriously considered, this to obtain a reliable and safe kiln, which can survive in this fast moving business.

6.3 Project evaluation

This project has been running for about a year now and, a quite few of the preconditions have changed during this period. However by approaching the project with solid assumptions a conclusion gradually emerged.
During the process it became clear that the Lingl line needs a major upgrade, something that was not at all obvious when we started the project (going to 4-shifts).

Concurrent engineering has the advantage that processes proceed faster. However, the more people got involved, the more ideas emerged.
The rewarding aspect is that the project has already shown benefits. This is indicated by the fact that production is already looking into ways of getting 4 shifts and management, including CEO and CFO, are in consultation, about how to proceed with the Turbo Tegelen II project.

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