TECHNICAL AND ECONOMIC EVALUATION OF AN INSTALLATION PROJECT OF A PILOT PLANT IN THE TECHNICAL ASSISTANCE LABORATORY OF A CERAMIC GLAZE PRODUCER

Francesco Bordignon
UNIVERSIDADE DE SÃO PAULO; Av. Prof. Mello Moraes, 2231 – 05508-900 – São Paulo, SP - Brasil
francesco.bordignon@poli.usp.br

Prof. Paulo Carlos Kaminski
UNIVERSIDADE DE SÃO PAULO; Av. Prof. Mello Moraes, 2231 – 05508-900 – São Paulo, SP - Brasil
pckamins@usp.br

Abstract. *The present paper analyzes the project of the creation of a pilot plant for the production of small batches of ceramic tiles in the technical assistance laboratory of a ceramic glaze manufacturer. The plant aims to reach the following targets: improve client service (greatly reducing the development time of new products and allowing a complete adaptation of the products to production conditions); reduce development costs; protect the glaze producer against industrial counterfeiting, up to the start-up; improve the glaze producer image. This paper describes, at first, the current development methodology and the advantages to be obtained by the new installation; suggests a pilot plant configuration; analyzes the possibility to recover some machines, normally existent in a glaze producer plant; indicates the technical features of the necessary equipment, evaluating the necessary investment; and finally, executes a financial analysis of the project.*

Keywords*: ceramic tiles, production, cost reduction.*

1. Introduction

The technical and artistic development of new ceramic tile products is the responsibility of the glaze supplier, which periodically (at least twice a year) develops new collections, creating the artistic idea and offering a preliminary glaze line.

In Brazil, the glaze producer's technicians develop about 80% of new collections based on the Italian production, world leader in technology and aesthetics, and 20%, limited to wall tiles, on the Spanish production, by using catalogues and specialized exhibitions.

It is assumed the hypothesis that the present study is directed to a high capacity glaze producer, which has financial, organizational and human resource capacities sufficiently developed to face the industry. In the Brazilian reality it is limited to international companies.

2. Current development methodology and related problems

The creation process begins with the digitalization of images (catalogue pictures or reproduction of natural rocks) by specific computer software and photograph devices, and continues with the preparation of the silk-screens ready to decorate the green support (biscuit). The next step is the development of glaze types and tonalities to obtain the desired result. If a structured mold is required to make a 3-D surface, a silicone one is prepared.

It is necessary to highlight that the products developed in the international market (Italy and Spain) show a very high quality (and high cost), using pure raw materials, innovative technologies and extremely sophisticated equipment. The derived national products must be adapted to the internal cost standards and be produced with local raw materials and the technology owned by the Brazilian producers.

Afterwards, the samples based on a pre-dried standard biscuit and in a restricted range of colors and visual effects are prepared to be submitted to the approval of the client, who examines them, defines the final sizes and can require alterations of color and effects. It is evident that the laboratory samples are different from the corresponding industrial product. In the following phase, a new set of samples based on the client's requests is prepared and a new presentation is made.

After the collection is accepted, the technical development starts, adapting the glazes to the chosen configuration and the operating conditions of each client, by identifying the chemical and mineralogical composition of the specific biscuit's raw material, the equipment parameters and the final cost. Further adaptations are made to the glaze producer's internal laboratory, followed by production tests (called semi-industrial tests) in the client's production lines, which are normally repeated between 2 and 5 times.

Other modifications, following the described sequence, are also required during industrial production because of changes in the client's parameters, for example in raw materials, depending on the extraction areas in the mines, decoration sequence, firing curve and so on.

The technical scheduling for conventional development can be estimated as follows:

- 1st development: between a week and 10 days;
- 1st submission for approval: between 2 and 5 days;

- 2nd development, based on the client's requests: about a week;
- 2nd submission for approval and definitive choice: between 2 and 3 days;
- 1st adaptation to the client's configurations: between 3 and 5 days;
- semi-industrial tests: 1 day (depending on equipment availability);
- final adaptations (3 or 4 repetitions, carried out in the client's premises): between 1 and 2 non-stop working days, up to 16 hours each repetition.

The development of a new collection requires approximately 90 days of a technician's work, corresponding to a period of 65 working days.

Tab. 1 shows the development phases and Fig. 1 shows an example of development cycle scheduling.

Table 1. Current product development sequence.

Phase	Activity	Site	Observations
1	1st development	Glaze Producer	creation of standard samples
2	1st submission for approval	Ceramic Producer	evaluation and modification requests
3	2nd development	Glaze Producer	modifications to standard samples
4	2nd submission for approval	Ceramic Producer	evaluation of modified samples
5	approval	Ceramic Producer	approval / further modification request
6	1st adaptation	Glaze Producer	adaptation to size and operational parameters
7	1st semi-industrial tests	Ceramic Producer	local tests
8	2nd adaptation	Glaze Producer	adaptations
9	2nd semi-industrial tests	Ceramic Producer	local tests
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n	further adaptations (up to 5)	Glaze Producer	adaptations
n+1	further semi-industrial tests (up to 5)	Ceramic Producer	local tests
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post-sales	adaptation and semi-industrial tests	Glaze Prod/Ceramic	new production parameter adaptation

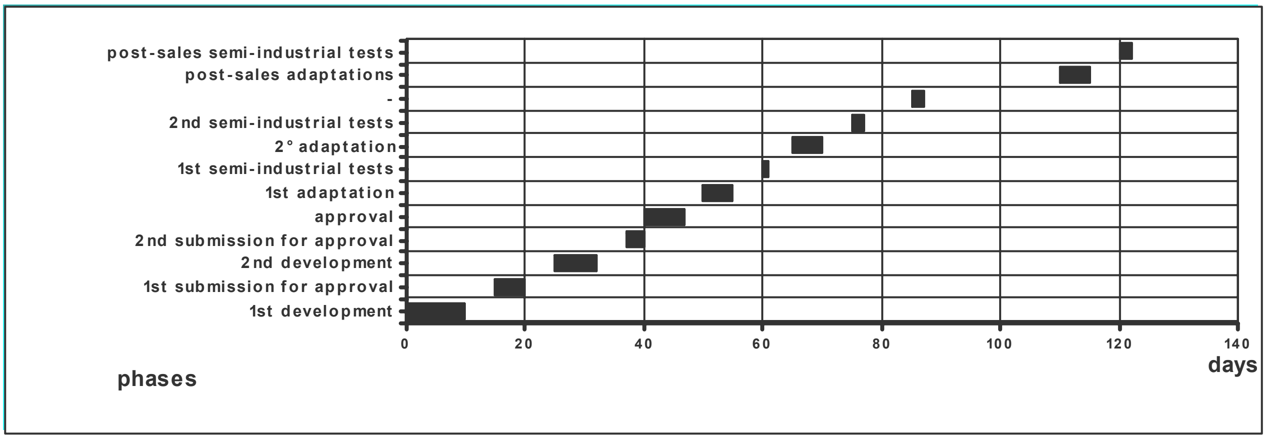

Figure 1. Current product development operating schedule.

The present sequence involves long periods and high costs, due to repeated technician's transportation, the supply of glaze batches in sufficient quantity for production tests and a careful programming, when the client schedules production stops, to make the lines available for tests.

The glaze adaptations to working conditions require high quantities of glaze raw materials (frits, pigments and additives) that must be available in the ceramic workshop so that the technicians can reformulate the adapted glazes quickly, repeating tests along the same section of access to the production line.

The greatest impediment to test execution is represented by the trouble created to the production process. A glaze change requires very careful cleaning of the glazing equipment before and after the test; causes product and production losses; uses the client's workforce and other program alterations. It is normally necessary to modify the kiln firing curve, whose thermal inertia is high; breaks in loading, added to product characteristic changes, create so much instability that time and care are required to stabilize the normal production conditions again. The client often delays allowing the use of the line, prioritizing his own needs and internal tests. This not uncommon event postpones the deadline for the new product development, greatly reducing the glaze producer's efficiency.

The simultaneous presence of competing glaze producers' technicians poses more problems. It is usual for tile producers to buy glazes and raw materials from different suppliers at the same time, so competitors often work side by side in the same workshop, either in new product development or for post-sales assistance.

This situation causes an unavoidable ease of access to classified information; competing technicians are thus able to examine or to obtain new product samples.

Approximately 70% of new products are caught before a supplying agreement is defined. Sometimes, the client himself, looking for a cost reduction in the new glaze, makes the samples circulate and, consequently, counterfeiting becomes easier.

Elimination of counterfeiting would allow a more efficient development and avoid unpleasant unfair competition, creating new business opportunities.

3. Targets

The targets that the new plant may reach can be classified as improvement of the services and development of new performances.

The first category includes a drastic reduction of new collection adaptation time, a noticeable reduction in the glaze producer's operating costs, a reduction in the troubles created to the client in carrying out the semi-industrial tests, and the protection of intellectual property.

It is possible to estimate that the pilot plant would permit to reproduce about 90% of the final production condition, by using the specific client's ceramic mass (body), press cycles and firing curves. In this way, it would be possible to conclude 80% of the development in the glaze producer's workshop, allowing about 80% of reduction in costs and a 50% reduction in development time. In parallel, the probability of new product counterfeiting would be reduced almost to zero. The greatest saving would occur in the new Northeastern ceramic cluster, which, due to the current market dimension, does not justify the existence of a local laboratory, making continuous technicians transport necessary. By making most of the development internally, it will also provide a more profitable and continuous scheduling for the technicians.

Tab. 2 and Fig. 2 show the development sequence with the pilot plant, which can be compared with the current situation, in Tab. 1 and Fig. 1.

Table 2. Product development sequence with the pilot plant.

Phase	Activity	Site	Observations
1	development	Glaze producer	creation of new line and panels
2	1st submission for approval	Glaze producer	evaluation and possible modification requests
3	adaptation	Glaze producer	modifications
4	2nd submission for approval	Glaze producer	evaluation of modified samples
5	approval	Ceramic producer	approval
6	semi-industrial tests and adaptation	Ceramic producer	local tests – final adaptations
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post-sales	adaptation	Glaze Prod/Ceramic	new production parameter adaptation

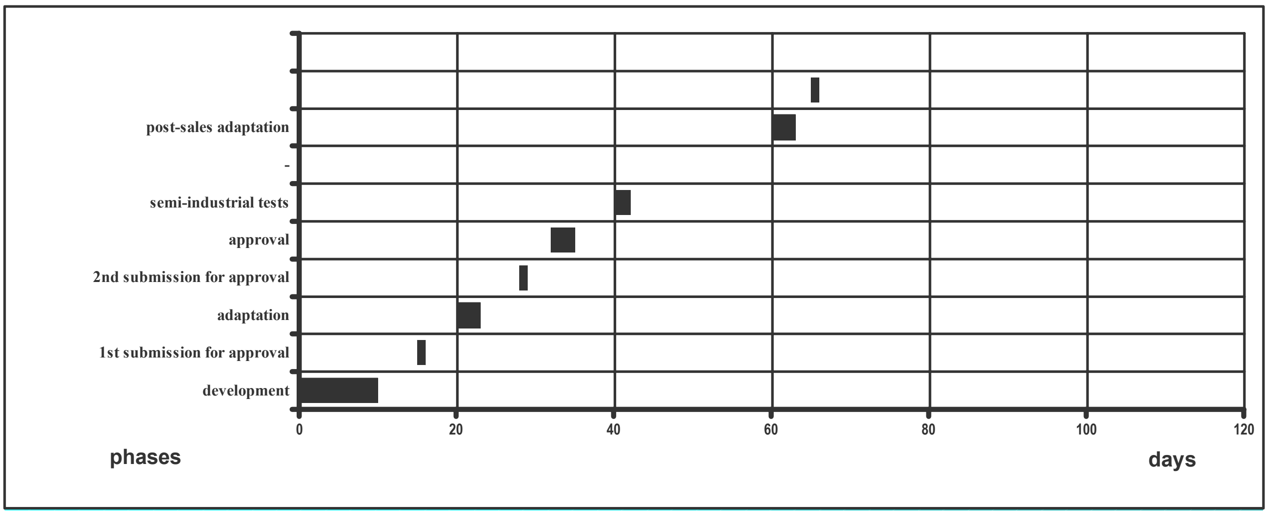

Figure 2. Product development operating schedule with the pilot plant.

The installation of a pilot plant would create new services for the client, because the presentation of a new collection would be made in a phase close to the final result, allowing higher security to the action of the client's marketing staff.

Once an advanced level in product development is reached, the pilot plant would permit the economical production of small homogeneous tile batches, which would be suitable to make great dimension panels (up to 4 x 2 m) and would enable the presentation of the new product with a higher visual impact, composed of special tiles, frames and accessories. Nowadays it is limited to single tiles of standard size.

The pilot plant will also permit to offer a technical consultancy service consisting of the development and improvement of the ceramic body. This service would provide an immediate economic return to the glaze producer. Using limited quantities of raw materials (1 or 2 t) in the glaze producer's workshop, it would be possible to develop formulas better-adapted to the client's work parameters or more economical firing curves, allowing a faster test in the pilot plant, with conditions very close to the industrial reality. Improving product quality and cutting costs makes the supplier's reliability stronger.

The current international market conditions open new business opportunities for Brazilian producers that can offer a good quality product; in this sense, cooperation with the client is fundamental in the loyalty process.

Market strategies continuously compel the client to manufacture new pre-series of products to be supplied to distributors, stores and show-rooms before the official product is launched; this tendency is highly prejudicial for everyone: the glaze producer is forced to offer high glaze quantities and some full-time technicians for free; the ceramic producer must provide the plant and support the high cost of the production of a pre-series, including normal production losses, long idle-time for firing curve alterations and kiln stabilization. The pre-series manufacturing in the pilot plant will create savings and also profits for the glaze producer, considering that the service can be charged.

An extension of this outsourced manufacturing service of small batches to the glaze producer would be feasible also for products in their life-cycle end phase or whose production is terminated, when small volumes are economically impracticable to be manufactured in the client's equipment.

Similarly, some special and out of standard size tiles could be produced, used for finishing and commonly manufactured by the so-called "*third fire*" process, which consists of decorating and firing a pre-fired and sometimes pre-glazed biscuit. This process requires specific equipment, currently not available in a ceramic tile producer's workshop; their purchase and installation involves high investments and the very limited production does not allow an acceptable profitability.

The pilot plant will also allow new forms of commercial partnerships with the glazing equipment suppliers, who, by making new equipment prototypes available in the glaze producer's workshop, will offer economic gains by avoiding investments in equipment. A joint development would cut the project time, permitting the quick offer of new glazes. The equipment supplier's savings would also be high, since it would not be tied to exhibitions and commercial events and would be able to offer practical demonstrations of the equipment functionality at only one site. It has to be considered that most glazing equipment suppliers are small Italian firms, with limited financial and technical personnel availability, which causes their access to the interesting Brazilian market to be often denied. Besides, up to 5 or 6 years ago, the equipment supplier was the only responsible for technological development and the glaze producer had the task to adapt glazes to the new equipment. Nowadays the tendency is reversed, the glaze producer being responsible for creating new solutions and leaving to the equipments the manufacturing; on the other hand, the equipment supplier is rarely in tune with the glaze producer to develop the needed equipment in a short time.

All the situations above guarantee not only great savings, but also noticeable improvement of the glaze producer's reputation and reliability in the market, which represents a competitive advantage, allowing an increase in sales and prices.

4. Pilot plant configuration

The implementation of the pilot plant demands the installation of various machines (Venturi, 1986), (Biffi, 2002), (Corbara and Emiliani, 2000) in a basic configuration to be made in the first phase of the investment, object of the analyses in this paper. To achieve an ideal or extended configuration, some other devices must be added; it can be done in a second step of the investment and, even if not analyzed here, it is useful to define the pilot laboratory layout.

4.1. Basic configuration

The basic configuration demands the equipment listed below:

- 1,000 t hydraulic press, including loading and feeding device, molds and auxiliary services;
- room static dryer (batch), with accessories;
- glaze mills (100 l; 250 l); with loading platform;
- modular glazing line, 30 m length, with inlet/outlet modules and the following glazing units:
    - inlet blower;
    - wetting station (water spray-gun);
    - 2 disc units (simple and double);
    - 2 airbrushes (floating and double);
    - 2 bell units (or more);
    - glazing die (thick layer glazer);

- o binder airbrush;
- o grit distributor machine;
- o engober;
- o flat silk-screen printing machine;
- o glazing device accessories (tanks and sieves, when required);
- roller kiln: single layer; 1,000 mm channel width, 16.8 m length; fast firing cycles: 25 - 80 min; maximum temperature 1,250 °C; ceramic fiber floating block roof (low thermic inertia); computer aided control system;
- weighing station: 2 t capacity;
- air-exhauster device: neck filter (dimensioned for 10 intake stations), pipelines.

The availability of auxiliary services to the pilot plant, such as electric energy, local lighting installation, gas, industrial water, compressed air, waste water collection lines (for floor and equipment cleaning) and dust exhaustion in some specific points, must be considered both when evaluating the investment and when detailing the project.

4.2. Expanded configuration

The following configuration can be adopted in a future expansion of the pilot plant and can be considered necessary to manufacture small batches of special tiles; it includes a second hydraulic press (400 t, with services and auxiliary devices); a second static dryer; a third glaze mill; the glazing line extension, including glaze units as a double disk unit, two airbrushes, a glazing die, a brushing unit, one or two rotating silk-screen printing machines, storage unit.

Fig. 3 shows a pilot plant layout example, considering both configurations.

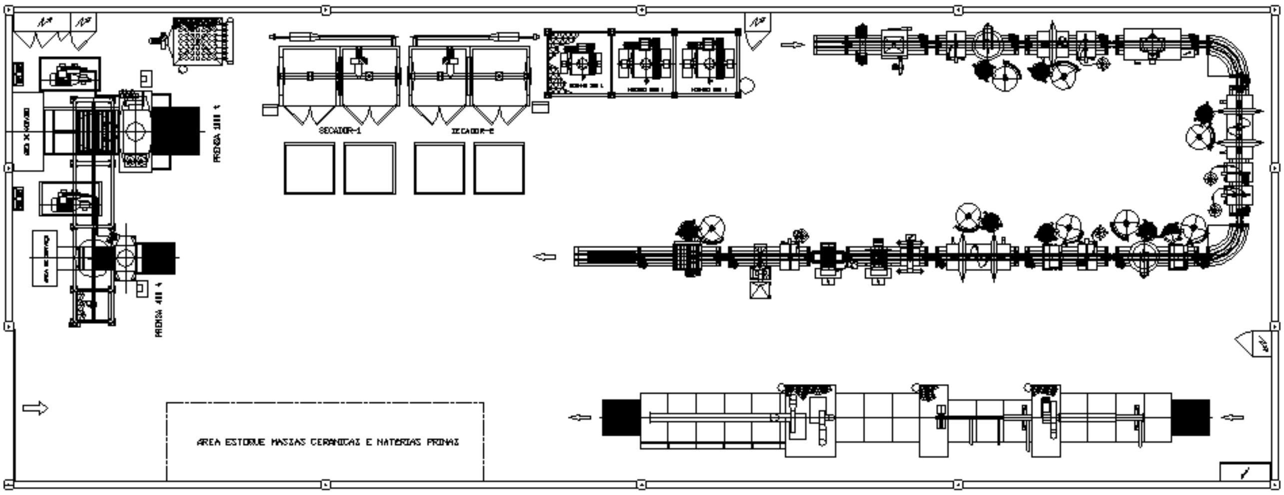

Figure 3. Pilot plant layout example.

5. Reuse of existing equipment

It is necessary to remember the initial hypothesis about the company dimension (see Section 1) to define a list of existing equipment; under these conditions it is possible to consider the following equipment as already existent and available to be rearranged in the pilot plant:

- static dryer;
- glaze mills (100 and 250 l);
- modular glazing line, partial (6-8 m);
- glazing units with accessories: wetting station, simple disc unit, double airbrush, 2 bell units, binder airbrush, grit machine.

6. Investment

In this section the needed investment to implement the pilot plant is estimated under the additional conditions and configurations previously described (Bordignon, 2004):

- hydraulic press: considering the high cost of a new machine and the low operating factor for laboratory use, the option is for the purchase of a second hand equipment. Presses with the required performances are obsolete for industrial production, but commonly exist in many Brazilian ceramic workshops, still installed, in good condition and with all the accessories, even if out of use. This kind of press does not exceed the normal transport standard size and weight, so a normal freight cost is considered;
- roller kiln: although it is easy to purchase a second hand equipment, the purchase of a new one is preferred, as it is the most delicate and important component of the whole installation; when disassembling, transporting and

reassembling the oven's modules, the refractory may be irreparably damaged. Some specific solutions are also imposed for laboratory use to improve flexibility and range of utilization: special refractory internal coating offers reduced thermal inertia and fast response to firing curve alterations; high efficiency lagging compensates the light refractory higher thermal conductivity; increased number of temperature and pressure measuring spots; over-refined supervisor; additional burners to reproduce special firing curves;

- the existing equipment will be rearranged without service; the investment calculates just the internal transport costs;
- auxiliary service installations, such as gas, industrial water, compressed air pipes and electric energy distribution, are considered existent and available to battery limits and with sufficient rate of flow to cover the installation requirement; the investment considered is limited to extending the piping up to the use points; for the electrical installations it is considered only the main distribution board;
- masonry work includes the housing for press and weighing station bases and the waste water collector raceways;
- engineering, design and supervision will be handled by internal staff.

Tab. 3 details the net and the total investments, including incidence of taxes.

Table 3. Investment

Equipment description	#	type	unit value	total value	transp/install	Total
press, accessories, services	1	U	130,000	130,000	5,000	135,000
press cooling unit	1	N	4,500	4,500	1,000	5,500
body loading device	1	N	8,960	8,960	3,500	12,460
static dryer /mills	1/2	U	existent	existent	1,800	1,800
mills loading platform	1	N	8,960	8,960	3,500	12,460
glazing line straight module	7	N	2,340	16,380	4,900	21,280
glazing line 90° curve module	2	N	4,000	8,000	1,200	9,200
inlet brush	1	N	900	900	300	1,200
inlet blower	1	N	1,600	1,600	300	1,900
wetting station/simple disk	1/1	U	existent	existent	600	600
double disk	1	N	11,770	11,770	300	12,070
floating airbrush	1	N	3,000	3,000	300	3,300
double airbrush/bells	1/2	U	existent	existent	600	600
glazing die	1	N	5,600	5,600	300	5,900
binder airbrush/grit distributor	1/1	U	existent	existent	900	900
engober	1	N	3,800	3,800	300	4,100
flat silk-screen printing machine	1	N	27,500	27,500	600	28,100
tank (+ 4 existent)	2	N	950	1,900	-	1,900
vibratory sieve (+ 4 existent)	2	N	2,300	4,600	-	4,600
roller kiln	1	N	438,500	438,500	11,500	450,000
weighing station	1	N	3,500	3,500	300	3,800
air-exhauster device	1	N	33,500	33,500	3,500	37,000
local lightening	turn-key	N	3,500	3,500	2,500	6,000
service piping (air-water-gas)	turn-key	N	22,000	22,000	-	22,000
masonry work	turn-key	N	16,500	16,500	-	16,500
electric installation (main board)	turn-key	N	33,000	33,000	-	33,000
TOTAL NET					**[R$]**	**831,170**
TOTAL (WITH TAXES AND CONTINGENCIES)					**[R$]**	**999,118**

Type: N = new; U = used.
Values in *Reais* (Brazilian currency).

Further general hypotheses:

- listed values are approximated and refer to a project budget; they were obtained through estimates, suppliers' information and extrapolation of similar service offers;
- for glazing line purchasing (modules and devices) a 30% discount is calculated based on market prices, due to the publicity that the installation of the equipment in the glaze producer factory represents;
- about taxes: ICMS and IPI are included; PIS (3.65%) and COFINS (5.6%) are not included, despite being used to calculate IPI, because they can be recovered during the current investment period (Bruni and Famá, 2002); ICMS is included in the total value and considers a reduced rate of 8.8%; its recovery, allowed on a 4-year period, is considered in the cash flow; IPI (4% average rate) is not recoverable;
- a contingency reserve is calculated, limited to 5% of the total investment value, because of accuracy in the estimate;
- totally self financed project;

- 10-year project life;
- the residual value is considered zero: the equipment's low final value will compensate just the disposal costs.

The design of the suggested installation layout (Fig. 3) determines a required area of approximately 600 m^2, assumed to be available and free in the workshop.

7. Financial analysis

The economic evaluation of this project analyzes the discounted payback and matches the Internal Rate of Return (IRR) with a minimum attractive rate.

Essential hypotheses and conventions herein used are listed below:

- investment cash outflow happens at the beginning of a period; revenues and operating expenses at the end;
- revenues are the earned savings subtracting the operating expenses;
- the required working capital and pre-operating expenses are zero;
- cash flow discount rate is fixed at 20 % a year;
- a minimum attractive rate of 30% a year is considered.

Operating costs include electric energy and gas and add, respectively, R$3,730and R$19,550. Compressed air, industrial water and consumables are disconsidered, as they are very limited and use the client's body.

Not estimating the investment to build the required area, the operating costs must include a value corresponding to the used area rent, calculated in R$2,040/month as 1% of an industrial warehouse building cost of R$204,000, based on a unit value of R$340.57/$m^2$ (SINDUSCON/SP, 2004, apud Pini, 2004).

The Brazilian ceramic market in 2003 exhibited 97 producers with a total of 125 factories and a production of 534 Mm^2 of ceramic tiles (ANFACER, 2004), supplied by 22 glaze producers (ABC, 2004); 4 of these were of high capacity and competed for about 80% of the whole market, with a market share between 15 and 20% each one.

The present analyses assume a 15% national market share for the observed glaze producer, which must serve 15 clients, each one with a demand of two new collections a year, corresponding to 30 new developments during a year.

The tasks of the glaze producer's technicians are divided into new product development (50% of the total time) and post-sales technical assistance (the other 50%); so on an annual basis of 242 working days, the technicians have about 120 days for new product development. Considering an average period of 65 working days to develop a collection, as evaluated in Section 2, each technician is able to prepare two new collections a year; it is deduced that the glaze producer needs between 15 and 16 technicians.

Earned savings resulting from the pilot plant installation consider reduction of technicians, operating costs and consumables, as follows:

- personnel reduction: even if each technician executes both development and post-sales assistance activities, it is possible to outline that 8 technicians work on development and 8 on assistance; attaining the targeted reduction of 50% in development time, it is possible to reduce the manpower by 4 units, leaving post-sales assistance unchanged (conservative assumption). The monthly average cost of a technician is analytically estimated at R$9,235; so a 4 unit reduction would permit to save R$36,940/month;
- operating costs: it is estimated a 20% saving, which means a reduction of R$1,090, corresponding to R$13,080/month;
- consumables: each semi-industrial test consumes about 300 kg of glazes; by reducing these procedures from 3 to 1, the earned saving is 600 kg of glazes for each development; on a basis of 30 developments/year, the cost saving reaches 18 t; considering a material average cost of R$2.0/kg (producer's average cost for silk-screen pastes, grits, compounds, etc.) the total saving adds up to R$36,000/year, corresponding to R$3,000/month.

Tab. 4 summarizes operating costs and management savings after the pilot plant installation:

Table 4. Monthly cost and saving summary.

Costs:	**R$**
electric energy	(3,728)
fuel (gas)	(23,270)
warehouse rent	(2,040)
Total Costs:	**(29,038)**
Cost saving:	
technical personnel reduction	36,940
operating cost reduction	13,080
consumable reduction	3,000
Total saving:	**53,020**
NET MONTHLY INCOME:	**23,982**

The annual net income is R$287,784.

ICMS recovery must be added in the first four years of operation, resulting in a total value of R$80,201, so the annual recovery is R$20,050, consequently in the first four years income grows to R$307,834.

The discounted payback (Motta and Calôba, 2002) is calculated by the discounted cash flow, using an annual discount rate of 20% and using the following formula (1):

$$DCF = -I + \sum_j Rj / (1+i)^j \tag{1}$$

where: I = investment; Rj = revenue during the year j; i = discount rate; j = period index, varying between 1 and 10.

The mathematical resolution of the payback formula (Hazzan and Pompeo, 2003) is 5.90 years, equivalent to 5 years and 11months.

IRR resolution gives an annual value of 27.52%, which, compared with the attractive rate, is just 2.5% lower.

8. Conclusions

The analyzed project arose from the identification of a common problem of several glaze producers: the high costs of new product development and the management of the technical assistance department. The main cause is a non-optimized work methodology that frequently forces the technicians to operate in the client's workshop, increasing transport costs, idle time and uncomfortable interference situations in the ceramic industry.

The installation in the glaze producer's workshop of a small ceramic pilot plant represents a possible solution to reduce many of the mentioned problems.

The evaluation indicates a feasible activity, showing a return that is higher than the financial cost, even a little below the attractivity limits commonly accepted for medium- to big-sized companies and defined by the current financial scenario.

It is important to point out that the present study considers analytically the direct saving but only describes the indirect ones; in fact, their definition in monetary terms would require complex analysis and involve market and customer satisfaction researches, which would imply high costs and long term, thus being incompatible with the scope of the present analysis.

It is also important to consider that it is not a profitable activity but an improvement in management and costumer service; that is why the return rate must be evaluated not only from a mathematical point of view but also involving many other considerations.

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