

## Flexible-lean processes optimization: A case study in stone sector

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### ARTICLE INFO

#### Keywords:

Ornamental stones  
AEC  
Lean construction  
Sustainability  
Lean thinking

### ABSTRACT

During the downturn in demand in Engineering and Construction Architecture (AEC) activities registered in 2007, the Cluster of Mineral Resources of Portugal (CPMR) put into practice an initiative to boost the Ornamental Stone sector, based on incorporating lean thinking concepts, combined with techniques and technologies to make production processes more flexible. This was called the *leanstone hornbook (LH)*. Since then, the *LH* has been adopted by several Portuguese Ornamental Stone (OS) companies. For these companies, using the *LH* means changing their operations to a new model based on (i) their participation in R&D consortium projects, (ii) incorporating the resulting innovations, and (iii) combining innovation with lean thinking. Based on a convenience sample of OS companies, the objective of this research was to assess the economic-financial impact of *leanstone operations* on Portuguese OS companies. Through a methodological framework based on Key Performance Indicators (KPI) and Innovation Outcomes (IO), indexed to companies' economic-financial performance, *LH* was found to generate a potentially positive impact in terms of sales volume, exports, investment capacity and net result.

### 1. Introduction

During the subprime crises (2008–2010), the reduction in Architecture, Engineering and Construction (AEC) activities has naturally led to a sharp contraction in demand for construction materials in Europe and the USA [1], which has negatively affected exports of Portuguese Ornamental Stones [2].

To mobilise this important sector for the Portuguese economy and based on incorporating lean concepts combined with flexible production processes, the Cluster of Mineral Resources (CPMR) of Portugal then initiated an innovation dynamic called the "*leanstone hornbook*"<sup>1</sup> (*LH*). Adhering to *leanstone* operations would then mean participating in R&D partnership projects, incorporating lean techniques and modern production technologies that are environmentally friendly and energy-optimized, which could add value and increase quality and flexibility [3,4].

It is in this context that the following research question arises: What is the economic and financial impact of *leanstone* operations on Ornamental Stone companies in Portugal?

The research carried out revealed that specific, updated literature on the OS sector is not abundant. Additionally, from the published papers available, it was found that most do not reflect, or refer to, the dynamics of this sector in the last decade, considered traditionalist and therefore often neglected and poorly evaluated.

Therefore, the guiding research of this empirical study was based on comparing the economic and financial results of two groups of companies: one group that joined the *LH* before 2010 and a second group of companies that kept the traditional form of operations.

This research aims to assess the gains of the *leanstone* operations model, comparing the performance of the two groups of companies from 2010 to 2018 and in terms of: (i) sales volume, (ii) exports, (iii) investment capacity and (iv) net income.

In selecting the participating companies, an objective and convenient sample was chosen, which was not randomly performed.

### 2. Lean thinking production system

Since its advent, industrialization has been based on a process of

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<sup>1</sup> [https://sim4.isq.pt/wp-content/uploads/sites/92/2018/03/20180315\\_Evora\\_03\\_CEL.pdf](https://sim4.isq.pt/wp-content/uploads/sites/92/2018/03/20180315_Evora_03_CEL.pdf): accessed December 10th, 2019.

continuous technological development, aimed at full satisfaction of the end customer, the unique solution for creating value [5].

However, at the dawn of the 20th century, the need to pursue this objective revealed two perverse effects: The excessive increase in bureaucracy and effective delivery times, with the consequent need to increase stocks [6].

Curiously, the structured response to this problem emerged from the automotive industry, not in the USA, but in Japan, as a result of intense technological and industrial evolution after World War II [7]. The creators of the term lean thinking, Womack and Jones (1996), listed five basic principles in their first edition of the work with the same name [8]: (i) value creation; (ii) definition of the value chain; (iii) flow optimization; and, (iv) pull system and perfection [9].

However, this systematization revealed some deficiencies [10], first of all, because it considers only the client's value chain [11] when in an organization there are not one but several value chains, that is, one for each stakeholder [12]. A second limitation was the very nature of the principles listed by these researchers. "If followed to the letter, they could lead organizations into endless cycles of waste reduction, ignoring the crucial activity of value creation through product, service and process innovation" [13].

It was from these limitations of the principles of Womack and Jones (1996) that new lean thinking principles emerged [14] such as (i) to know who we serve, (ii) to define values, (iii) to define value chains, (iv) to optimize the flow, (v) if possible, to implement the pull system, (vi) to seek perfection and (vii) to continuously innovate [15].

Since these principles are easy to list, but difficult to implement, subcategories have emerged in order to facilitate the adoption of lean management in organizations [16], namely, from the public, by several authors of the Toyota Production System (TPS) operations management model [17], namely [18]: (i) Supply Chain Management (SCM) - the supply chain involves all organizations that are engaged in manufacturing or providing services, and it is through each one that value is created and transferred to the end customer [19]; (ii) Client Service (CS) - the end customer is the reason for each organization to live, it is for them that the entire chain is coordinated and creates value [20], where service is increasingly valued from their perspective. The service is, therefore, a critical differentiation factor in all organizations [21].

### 3. The Ornamental Stone sector in Portugal

Despite its size, Portugal has a significant diversity of stones suitable for ornamental use [22]. According to data provided by ASSIMAGRA (2019),<sup>2</sup> for the year 2018, the Portuguese OS sector [23]: (i) generates over 18,000 direct jobs, (ii) exports to 116 countries, (iii) Portugal is the 9th country in the world in International Trade, (iv) the 2nd country in the world in International Trade per capita, (v) exports cover imports by 823%, (vi) 45% of exports are outside Europe, (vii) has the 2nd national position in Gross Value Added (GVA), and (viii) is one of the main generators of private employment in inland regions [24].

### 4. The flexible lean operations

Recent studies [22–24] indicate that the positive results observed in the sector since 2005 may be related to the progressive adoption of innovative practices and technologies designated *leanstone hornbook*<sup>3</sup> as well as a professional and global marketing stance [1].

Starting in 2004, the movement to mobilise the Portuguese OS sector to reduce waste and improve flexibility [25] has had as its main milestones Technological Innovation Projects in consortium, which have resulted in a new generation of technologies, concepts and innovative

practices customized to the needs of Portuguese OS companies. The *leanstone* movement [24] emerged from a process of cross-fertilization and technology transfer between the footwear sector and the OS sector [26], through the Facap,<sup>4</sup> Fatec,<sup>5</sup> Newwalk,<sup>6</sup> Jetstone<sup>7</sup> and Inovstone<sup>8</sup> projects [27]. These will have been decisive in making many companies from both sectors believe that evolving in technology, would help their search for competitiveness [24].

The Jetstone Mobilizer Project was one of the first major thrusts of leanstone [23,24], bringing to the OS sector flexibility, agility in responding to customized projects [28], reduction of raw material waste and improved energy efficiency, which in turn led to increased productivity, improved working conditions, the ability to create new products and services, and ultimately contributed to the evolution of the value chain [22,23]. Completed in 2013, the Inovstone<sup>9</sup> Project acted transversally in all stages of the valorization of natural stone [29], including extraction, transformation and finally the restoration of the Historical Heritage in stone [30].

Following the implementation of innovations resulting from the Jetstone Project [31], there was an increase in OS companies' exports in 2005, which began by "importing" the model that the Portuguese Footwear Industry had been following since the last decade [32]. After a slight decline in 2008, OS exports resumed growth the following year. According to data published by Assimagra<sup>10</sup>, this trend continued until 2015, with only a slight correction, perhaps resulting from the exceptional years of 2013 and 2014.

Also revealing the dynamics and sustainability of the Portuguese OS sector is the *Sustainable Exploitation of Resources in the Estremenho Limestone Massif* Project in co-promotion between Assimagra, Icnf, Dgeg, Cevalor, Lneg, Visa Consultores, Biodesign, Municipalities of Alcobaca, Porto De Mós, Rio Maior, Santarém, IPL and about 100 companies from the Pnsac<sup>11</sup> exploration quarries, which was awarded the 1st National Prize in 2015 in its category - Supporting *The Development of Ecological Markets and Resource Efficiency*.<sup>12</sup>

Nevertheless, to reduce the strengths of the Portuguese OS sector to just accounting numbers would be clearly unfair, as Fernandes [33] points out (...) "any business whose results are only accounting records is a poor business." [33]. With an average salary that is substantially higher than the national average, the Portuguese OS sector has a ballast of almost two decades of incorporating new techniques and production technologies, which has allowed it to attract and incorporate critical mass through the admission of thousands of university graduates, according to Assimagra, and thus acquire an attitude oriented towards innovation [26]. This predisposition towards continuous innovation, seen in recent years, has led to the development of products, means of production and a management approach, all aimed at creating value for the customer [34], which may be a good indicator of the possible future response of OS companies in the context of the approaching Building Information Modelling (BIM) procurement and surely one of its strengths to be taken into account [35]. The fact that the *LH* has come to encompass, from the Inovstone project onward (Image 2.1), not only OS transformation but

<sup>4</sup> First Mobilizer Project to develop innovative technologies to produce Footwear.

<sup>5</sup> Second Mobilizer Project to develop innovative technologies to produce Footwear.

<sup>6</sup> Third Mobilizer Project to develop innovative technologies to produce Footwear.

<sup>7</sup> First Mobilizer Project to develop innovative technologies for Ornamental Stones.

<sup>8</sup> Second Mobilizer Project to develop innovative technologies for Ornamental Stones.

<sup>9</sup> Inovstone Mobilizer Project is a consortium of 15 entities from the national business and scientific environment (<http://www.valorpedra.com/inovstone>).

<sup>10</sup> Assimagra.pr.

<sup>11</sup> Parque Natural das Serras de Aires e Candeeiros

<sup>12</sup> Frezite Group President.

<sup>2</sup> <https://www.assimagra.pt/>: accessed October 8th, 2019.

<sup>3</sup> Set of practices and technologies to reduce waste and provide flexibility in production.

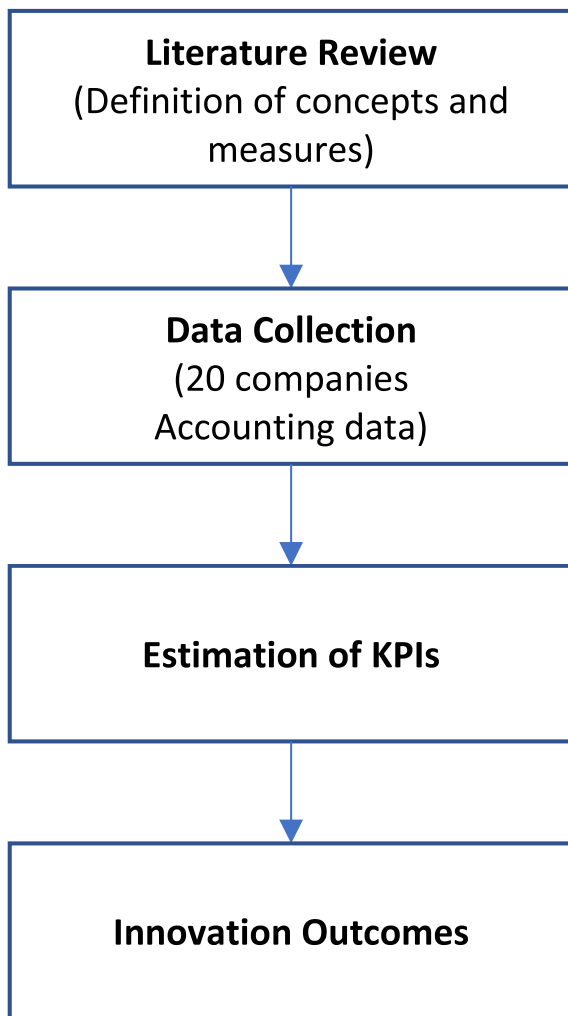


Fig. 1. Methodology flowchart.

also the upstream phase of raw material production (extraction of blocks) has allowed companies to acquire a more realistic perception of the full supply chain [36].

5. The leanstone hornbook

Observing the basic principles of the R&D Projects described above, we may accept that *leanstone operations*, to which more and more OS companies are adhering, are not only based on applying lean principles, but also on flexible production [34]. The starting point is the gradual elimination of all manifestations of waste (everything that from the perspective of the end client does not add value) and the adoption of a "whole" approach as a solution for the "particular case", resulting in customized production [28,34]. This path of incorporating technologies conceived under flexible, lean awareness [37], throughout the supply chain of the Ornamental Stone sector, resulted in a new concept, popularized by the Portuguese OS sector as *leanstone hornbook* [29]. The companies that adopt the principles of the *leanstone hornbook* transform their operations into *leanstone operations*.

Through lean principles, in *leanstone operations*, each little increment towards continuous improvement is supported in PDCA (Plan, Do, Check, Action) cycles, repeated continuously until perfection is achieved [14]. To obtain a detailed picture of the supply chain, without excluding any of the stakeholders and to understand how they relate to each other [18], the Supply Chain Operations Reference (SCOR) model is usually used [38]. In a context of uncertainty, where constant strategic realignment is

Table 1  
Turnover evolution 2010–2018.

Year (N)	KPI#1 TURNOVER EVOLUTION 2010–2018 (%)	
	Traditional Operations	Leanstone Operations
2010	0	0
2011	5	-2
2012	0	3
2013	-10	7
2014	-8	16
2015	-15	13
2016	0	17
2017	6	31
2018	-3	39

essential for management, the *leanstone hornbook* suggests that the manager should focus on business strategy, aligning processes [39], taking decisions from the real facts and promoting the implementation of lean thinking [40,41]. Additionally, the *leanstone hornbook* proposes that tactical and operational management be oriented to evaluating the root-causes of problems, oriented to the creation of value for the client.

6. Research methodology

The Ornamental Stone sector is a sector where the asymmetry of information, power of influence and lack of a legislative framework do not provide a favourable context for in-depth research [42]. In this context, the possibility of interviewing the managing directors of the sampled companies influenced the choice of companies [43].

Therefore, an objective and convenient sample was chosen, as it is intended to meet a certain cumulative and previously specified criteria. The sample will thus be composed of two groups of companies: (i) the Traditional Operations Group of Companies, consisting of ten companies that operate in Portugal, and at least until 2018, opted to keep their traditional operations, and (ii) the Leanstone Operations Group of Companies, consisting of ten companies that operate in Portugal and adhered to *leanstone* operations before 2010. The empirical data was obtained with the support of the companies' managing directors.

In the twenty companies selected and to compare the performance of these two groups of companies in the period from 2010 to 2018, data were collected directly from their official accounting documents. All the data collected had the consent of the respective companies, all of which operate in Portugal and carry out the activity of Ornamental Stone production. At the request of the companies' management, the names or brands associated with them will not be disclosed in this work. However, by agreement with these same directors, there will be no limitations to academics' re-evaluation of the same data, if it is for the same purpose as this research.

In this paper, we present a simple methodological path (see Fig. 1). Starting by constructing the bases of the study (i) through the literature review, then (ii) collecting data from twenty companies from the Portuguese Stone Sector, all them similar size wise, (iii) estimating the KPI's

Table 2  
Exports evolution 2010–2018 (%).

Years (N)	KPI#2 EXPORTS EVOLUTION 2010–2018 (%)	
	Traditional Operations Group of Companies	Leanstone Operations Group of Companies
2010	32	20
2011	45	30
2012	37	26
2013	22	48
2014	31	52
2015	28	45
2016	35	56
2017	31	62
2018	24	59

**Table 3**  
Investment evolution 2010–2018 (%).

Years (N)	KPI#3 INVESTMENT EVOLUTION 2010–2018 (%)	
	Traditional Operations Group of Companies	Leanstone Operations Group of Companies
2010	1,2	2,2
2011	2,1	2,5
2012	5,2	2,6
2013	3,1	3,7
2014	0,8	7,1
2015	0,3	4,1
2016	0,5	3,1
2017	0,3	4,7
2018	0,1	5,2

**Table 4**  
EBIT evolution 2010–2018 (%).

Years (N)	KPI#4 EBIT EVOLUTION 2010–2018 (%)	
	Traditional Operations	Leanstone Operations
2010	1	-5
2011	9	8
2012	-1	1
2013	8	12
2014	9	17
2015	2	23
2016	4	15
2017	3	19
2018	2	21

and finally (iv) the Innovation Outcomes through regression analysis to evaluate the process and predict the respective behaviour. We believe that this methodology is quite simple, besides that, we include a flow-chart in order to keep it clear.

**7. Data collection, the KPI and Innovation Outcomes (IO’s)**

As described above, this work aims to assess the economic and financial impact of *leanstone* operations on the Ornamental Stone industries in Portugal, from the accounting records of the companies in the sample. In the previous section, quantitative data were collected and recorded for both groups of companies. The KPIs presented in Tables 1–4 show the average value of data collected for each of the twenty companies in the sample. Following the methodological procedures already detailed in this research, the data collected will be used to assess the Key Performance Indicators (KPI) and Innovation Outcomes (IO) related to the two groups of companies.

**7.1. Turnover Evolution**

The “Turnover” expression refers to the total value of goods and services sold by a given company, taking into account a set period of time for that analysis [44]. Generally, turnover is the net result of sales and services rendered, related to the normal activities of companies or other entities, during a certain period [45]. Based on the accounting data, in this research, turnover from 2010 to 2018 in terms of annual sales of products, goods and services rendered was recorded for each of the twenty companies in the sample.

The KPI#1 (Equation (1)), represents the annual variation, relative to the previous year, of the total turnover of each group of companies studied, from 2010 to 2018, considering in both groups o companies, the year 2010 as a zero-turnover year.

$$KPI\#1_{TURNOVER\_EVOLUTION,2010-2018(\%)} = \left( \frac{TOTAL.TURNOVER.Year(N)}{TOTAL.TURNOVER.Year(N-1)} - 1(\%) \right) \tag{1}$$

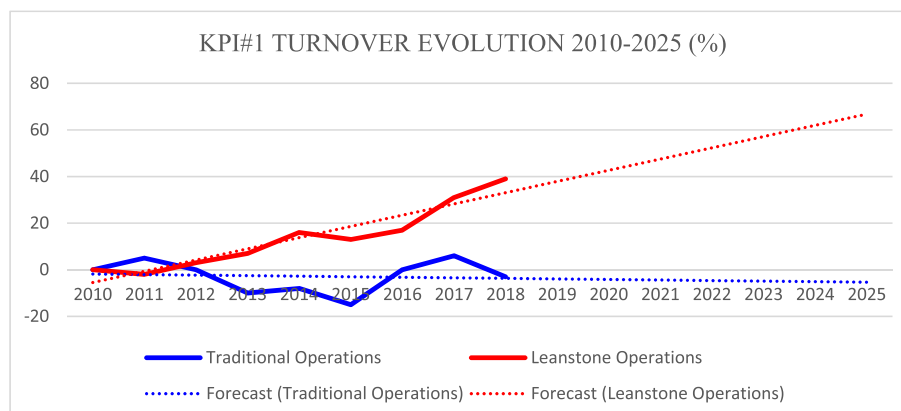
Analysing the evolution of average turnover, in the period 2010–2018, in the *Leanstone* Operations Group of Companies, the KPI#1 was found to evolve positively. On the other hand, for the same period, in the Traditional Operations Group of Companies, KPI#1 was found to stagnate (Fig. 2).

Based on these results, the linear trend of the evolution of turnover was defined through the respective Innovation Outcome (IO) (obtained by linear regression), and from these, the turnover for 2025 was forecast, for both groups of companies. Analysing the evolution of turnover in both groups, in the group of companies operating in *leanstone* mode, since 2010 the KPI indexed to the evolution of company turnover (KPI#1- $TURNOVER\_EVOLUTION,2010-2018(\%)$ ) was found to be positive. Moreover, this result is in line with the Innovation Outcome value indexed to the turnover growth forecast, which was (+4.8%) per year. This positive trend contrasts with the negative trend in the group of companies that have chosen to keep their traditional operations, for which the IO indexed to turnover reveals a negative trend forecast, equivalent to (-0.23%) per year.

**7.2. Exports Evolution**

Selling products outside domestic borders is a key aspect of national economies [46]. Depending on the type of transaction, there are two varieties of exports: commercial exports related to the sale of products that need to go through customs procedures, and non-commercial exports, such as the sale of samples, which are not subject to payment of fees or taxes [42].

From the accounting data on the twenty companies in the sample, for the purpose of this research, the value of exports was recorded from 2010



**Fig. 2.** KPI#1 | turnover evolution 2010–2025 (%).

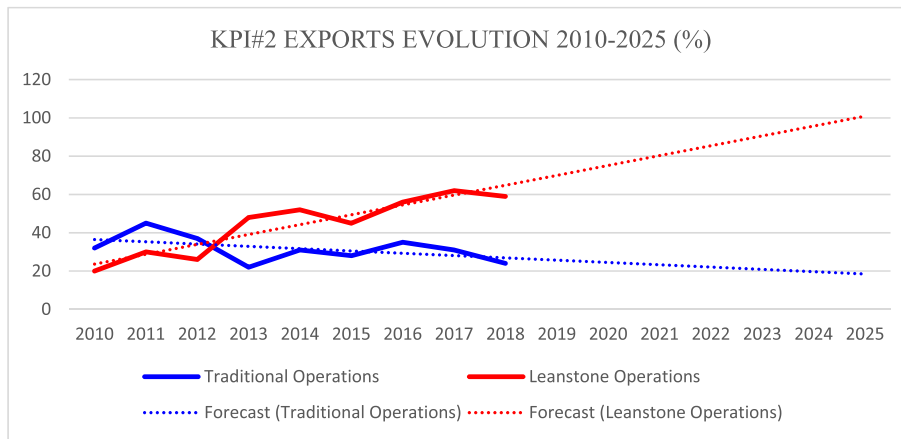


Fig. 3. KPI#2 exports evolution 2010–2025 (%).

to 2018. Equation (2) represents the relation between the total amount exported and the total value sold, by each group of companies: “Relative\_Exports”.

$$\text{Relative\_Exports} = \left( \frac{\text{TOTAL\_EXPORTS}}{\text{TURNOVER}} - 1 \right) \quad (2)$$

The related KPI#2 was assessed (Equation (3)) representing the variation of the Annual Relative Exports, on each group of companies studied, in relation to the previous year, from 2010 to 2018.

$$\text{KPI\#2}_{\text{EXPORTS\_EVOLUTION}_{2010-2018(\%)}} = \frac{\text{Relative\_Exports\_Year}(N)}{\text{Relative\_Exports\_Year}(N-1)} - 1 \quad (3)$$

Analysing the evolution of exports, (2010–2018), it was found that for the *leanstone* Operations Group of Companies, the KPI#2 value evolved positively. Meanwhile, for the same period, the KPI#2 value of the Traditional Operations Group of Companies decreased slightly (Fig. 3).

Based on these results, the linear trend of the evolution of exports was defined through the respective Innovation Outcome (IO) (obtained by linear regression), and from these, the exports for 2025 was forecasted, for both groups of companies.

Analysing the evolution of exports in both groups, in the group of companies operating in *leanstone* mode, since 2010, the KPI indexed to the evolution of exports ( $\text{KPI\#2}_{\text{EXPORTS\_EVOLUTION}_{2010-2018(\%)}}$ ) was positive. Moreover, the IO indexed to the export growth forecast, also tends to grow (+5.15%) each year. This result contrasts with the negative trend in the group of companies that have chosen to maintain their traditional operations, for which the IO shows a negative growth trend of (–1.2%) per year.

### 7.3. Investment evolution

Investments are actions taken with the purpose of obtaining profit or benefit [47]. For example, an investment involves a cash disbursement equivalent to a value in exchange for a higher amount [48]. Investments are common practice in a market economy that allows resources to be mobilized with relative ease and efficiency from less productive sectors to more productive ones [49]. In the case of Ornamental Stone companies, large investments are usually related to the acquisition of productive assets, so this activity is usually considered investment intensive [24].

Based on the accounting data, in this research, the amounts invested annually by each of the twenty companies from 2010 to 2018 were recorded. Equation (4) represents the relation between the total amount exported and the total value sold, by each group of companies: “Relative\_Investment”.

$$\text{Relative\_Investment} = \left( \frac{\text{TOTAL\_INVESTMENT}}{\text{TURNOVER}} \right) \quad (4)$$

The related KPI#3 was assessed (Equation (5)) representing the variation of the Annual Relative investments, on each group of companies studied, in relation to the previous year, from 2010 to 2018.

$$\text{KPI\#3}_{\text{INVESTMENT\_EVOLUTION}_{2010-2018(\%)}} = \left( \frac{\text{Relative\_Investment\_Year}(N)}{\text{Relative\_Investment\_Year}(N-1)} - 1 \right) \quad (5)$$

Analysing the evolution of the investment evolution (2010–2018), it was found that in the *Leanstone* Operations Group of Companies, the KPI#3 value was quite stable annually, or even revealed slight *growth*,

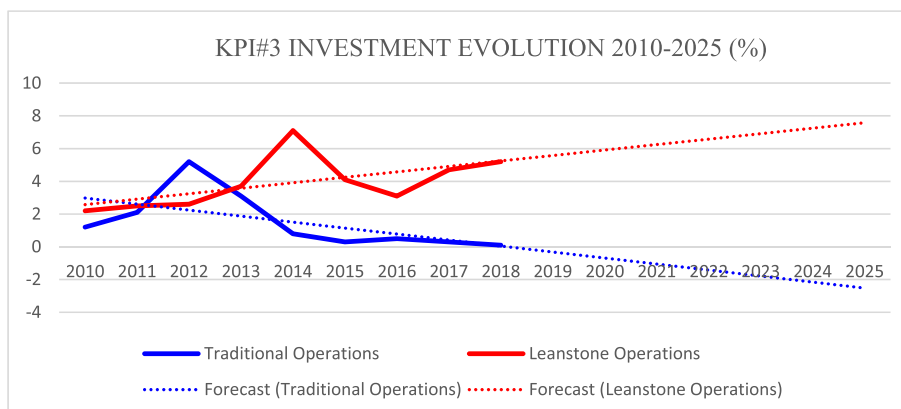


Fig. 4. KPI#3 investment evolution 2010–2025 (%).



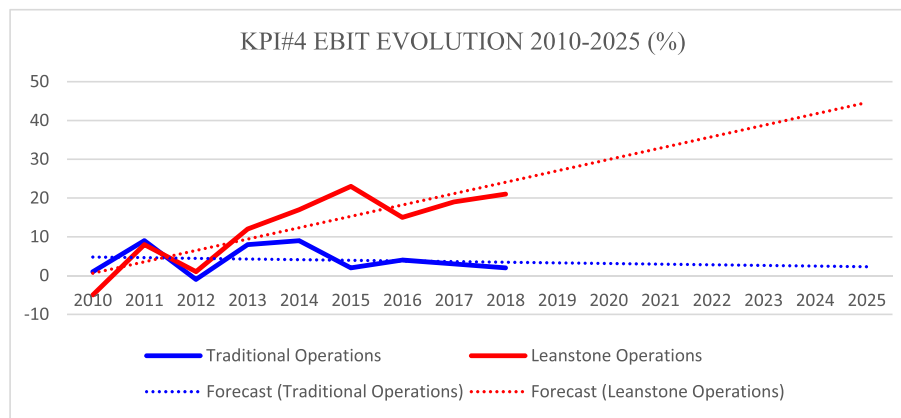


Fig. 5. KPI#4 EBIT evolution 2010–2025 (%).

while for the same period, the KPI#3 value of the Traditional Operations Group of Companies decreased significantly (Fig. 4).

Based on these results, the linear trend of the evolution of investment was defined through the respective Innovation Outcome (IO) (obtained by linear regression), and from these, the investment for 2025 was forecasted. Analysing the evolution of investment in both groups, in the group of companies operating in *leanstone* mode, since 2010 the (KPI#3<sub>INVESTMENT\_EVOLUTION\_2010-2018</sub>(%)) was positive. This result is in line with the forecast trend of this group of companies to maintain investment levels, with growth being slightly positive (+0.33%) each year. In the group of companies that have chosen to keep their traditional operations, the IO reveals a negative growth trend forecast of (−0.37%) per year.

7.4. Evolution of net income

In this research, companies’ net incomes were obtained from their balance sheets, recorded under Portuguese law. The concept of EBITDA - Earnings before Interest, Taxes, Depreciation and Amortization is a measure of the organization’s profit [50]. EBITDA reveals the company’s profit in its operating results, including depreciation and amortization [51]. Depreciation and amortization do not imply monetary outflows from the company’s cash but is rather an accounting measure for wear and tear, of machines for example, which generate income [52].

The concept of EBIT - Earnings before Interest and Taxes, in turn, represents the difference in the company’s income and expenses in the period, i.e. the gains and losses in order to carry out the final activity [53]. Its value serves as a basis to show how the company’s operation is going, as well as the gains or losses in interest or income tax payable [52]. Based on the accounting data, the EBIT figures for the twenty companies from 2010 to 2018 were recorded in this research.

Based on the accounting data, in this research, the EBIT figures of each of the twenty companies from 2010 to 2018 was recorded. Equation (6) represents the relation between the total Net Income and the total value sold, by each group of companies: “Relative\_Net\_Income”.

$$Relative\_Net\_Income = \left( \frac{TOTAL\_NET\_INCOME}{TURNOVER} \right) \tag{6}$$

The related KPI#4 was assessed (Equation (7)) representing the variation of the Annual Relative Net Income, on each group of companies studied, in relation to the previous year, from 2010 to 2018.

$$KPI\#4_{NET\_INCOME\_EVOLUTION\_2010-2018}(\%) = \left( \frac{Relative\_Net\_Income\_Year(N)}{Relative\_Net\_Income\_Year(N-1)} - 1 \right) \tag{7}$$

Analysing the evolution of EBIT during the period 2010–2018, it was found that for the *Leanstone* Operations Group of Companies, the KPI#4

value was quite positive over the period, while for the same period the KPI#4 value of the Traditional Operations Group of Companies decreased significantly (Fig. 5).

Based on these results, the linear trend of the evolution of the profit was defined through the respective Innovation Outcome (IO) (obtained by linear regression), and from these, the turnover for 2025 was forecasted. Analysing the evolution of EBIT in both groups, the group of companies operating in *leanstone* mode performance, since 2010, shows a KPI indexed to the evolution of company profit (KPI#4<sub>EBIT\_EVOLUTION\_2010-2018</sub>(%)) was positive. This result is in line with the value of the IO indexed to the EBIT growth trend forecast, which is predicted to be (+2.93%) annually. This positive trend contrasts with the negative trend in the group of companies that have chosen to maintain their traditional operations, for which the IO indexed to the net result reveals a forecast of stagnation or even reduction by (−0.17%) per year.

8. Conclusions

This research aimed to assess the performance gains of the *leanstone* operations model, comparing the turnover, exports, investment and net income of the two groups of stone companies, from 2010 to 2018: One Group including ten SME stone companies that operate in Portugal, and at least until 2018, opted to keep their traditional operations and another Group of ten different companies that also operate in Portugal and adhered to *leanstone* operations before 2010.

From this research, it was found that in terms of evolution of turnover, the group of companies operating in *leanstone* mode, have shown a positive annual turnover growth of (+5,0%) above to the group of companies that kept their traditional way of operating.

Moreover, it was found that in terms of exports performance, the group of companies operating in *leanstone* mode, have shown a positive annual export growth of (+6,4%) above to the group of companies that kept their traditional way of operating.

Moreover, it was found that in terms of investment capacity, the group of companies operating in *leanstone* mode, have shown a positive annual investment growth of (+0,7%) above to the group of companies that kept their traditional way of operating.

Moreover, it was found that, in terms of net profit obtained, the group of companies operating in *leanstone* mode, showed a positive annual net profit of (+3,0%) above the group of companies that maintained their traditional way of operating.

From the values found for the Key Performance Indicators and Innovation Outcomes, indexed to companies’ economic and financial performance, we can conclude that adoption of the *leanstone hornbook* generates a potentially positive impact, namely in terms of turnover, exports, investment capacity and profit. From these conclusions, Portuguese Ornamental Stone companies are recommended to adopt the *leanstone hornbook*.

### 8.1. Suggestions for future investigations

In the context of this Research Problem, we may consider as possible future developments, dynamic analysis of the cost-benefit relationship and interpretation of the frontier conditions, related to the investment required to operate in *leanstone* mode.

### Author contributions

Conceptualization, A.S.; methodology, A.S. and L.C.; formal analysis, A.S, L.C and A.D.; investigation, A.S, A.D. and L.C.; data curation, A.S and A.D; writing—original draft preparation, A.S.; writing—review and editing A.S., A.D and L.C.; visualization, A.S., A.D and L.C; supervision, L.C.; funding acquisition, A.S., A.D and L.C.

### Declaration of competing interests

None.

### Acknowledgments

This work was supported by CEI, Companhia de Equipamentos Industriais and Inovstone4.0®, Tecnologias Avançadas e Software para a Pedra Natural, POCI-01-0247-FEDER-024535 INOVSTONE 4.0. The authors also acknowledge the financial support from National Funds of the FCT – Portuguese Foundation for Science and Technology within the project«UIDB/04007/2020».

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