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PROJECT AUDIT

KEYWORDS
Audit • Project Management • Project Maturity • Civil Construction

Audit as a tool for PROJECT MATURITY CERTIFICATION in heavy civil construction

• ABSTRACT •

Organizational learning stems from the synergy of human resources, using their qualification in the results of projects whose maturity may be assessed based on metrics that are still unavailable. These metrics are the first contribution of the present study. The analysis of two case studies of complex terminals, guided by the Front-End Load culture of gate approval for strategic advancement as a business organization, shows that audits are essentially able to measure the level of stakeholders in their consulting, inspection, management, and contractor roles, thereby assessing their productivity and, moreover, their ability to perform the contract without exceeding risks, costs, and deadlines. The analysis clearly shows that the audit should be used as a tool for project maturity certification in heavy civil construction based on this study.

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1. INTRODUCTION

We live in an evolving and technological changing world that is filled with numerous market challenges. Today, the markets are comprised of a variety of products and services that focus primarily on serving the general populations' changing wants and needs.

In the industrial context, learning is the process of data accumulation throughout the desired and expected product (or process) life cycle, that is, long-lasting knowledge (Huber 1991). Learning is directly related to the use of the executive workforce because it may affect events with an impact on new personal and organizational knowledge, inclusively increasing the levels of legitimacy and the prospects of market survival (Meyer and Rowan 1977). The present study examines the organizational scope from this perspective (Malerba 1992). Maturity, at a productivity level, is reached as long as an organization is subjected to the rite of passage, that is, the audit as certification tool, which is a means of certifying the future success of the present project, currently with extremely low levels of maturity (Wolters Kluwer 2013).

Audits stimulate the exchange of experiences in strategic learning without disregarding the specific role of other players (Hobday 2000) who bring the acquired knowledge to others after reaching maturity, thereby possibly minimizing the costs and risks involved in similar situations. The present study focuses on the heavy civil construction industry, using mathematical models adapted to the reality-problem (Grosse et al. 2015). The effects of audits are positively perceived, but the academic literature must overcome this clearly reflexive condition. For example, the maturity model was constructed to assess the ability to develop products and services (CMMI Product Team 2010) or gather best practices (PMI 2013).

Presently, concrete cases promising to redesign the traditional learning curve (Anzanello and Fogliatto 2011) into new formats are reported, specifying moments characterized according to circumstances that have been well analyzed from the managerial perspective, which was the general objective of this study. The *description of moments that are suitable for specific changes that determine paradigm shifts in curve design according to vocations and that bring benefits to organizations*, which are under the spotlight, is one of the specific objectives of this study.

The subject of infrastructure construction in heavy civil engineering, characterized in *two relevant, representative, and paradigmatic case studies*, in the first years of the present decade, *will be used to highlight the importance of auditing for approvals*, which is the second main objective of this study. Accordingly, the present study aims to further contribute to a generalization that is applicable to such large construction works.

For this purpose, this study performed a *(i) literature review* of the three main topics studied herein, maturity, learning, and productivity, using complementing curves, each encoded with terms considered specific to the status of companies operating in this sector. A detailed analysis of these curves shows levels, and even points, which may make it possible to establish the relationship with specific time points to properly evaluate its condition using gate approval, highlighted by a particular method, subsequently using the audit and its tools to rate the progress.

After this review, the proposed *(ii) method* was applied to demonstrate its applicability according to two questions and one proposition used as the unit of analysis. The logic connecting the data and interpretation criteria was exemplified in *(iii) case studies* that are added and corroborate the proposed convention used in heavy civil construction as a generalization, analyzing the results within the so-called reality-problem. The first case study analyzes rail yard drainage, and the other focuses on a complex system of wastewater treatment in a container terminal.

Doing so made it possible to broaden the discussion of theoretical curves to the pragmatism examined herein for the scientific and professional community, in addition to its relevance, thereby making it possible to establish the *(iv) conclusions and final considerations of the study*, suggesting improving project monitoring and control processes through audits. Although this may be considered an obstacle to the Lean Construction model (Salem et al. 2006), the present study is not conducted as an antithesis but as a counterpoint that considers the alarming abuses observed in complex heavy construction works that lack the unequivocal transparency of project balance sheets required for certification.

2. LITERATURE REVIEW

The discussion is based on the analysis of maturity curves, consolidated from a learning perspective, according to a specific productivity achieved. This assessment of maturity depends on the cognitive effects measured in the following three dimensions: knowledge (the capacity to perform different tasks), attitude (the willingness to perform them), and actions (actually performing them; (Andersen and Jessen 2003), perceiving the real world as a different practical experience that immerses the individual in an institutional structure, which promotes as much synergy with others depending on the management system.

In general, this perspective, from the individual to the collective, includes machines and other similar resources, enabling the qualitative assessment of the heavy civil construction environment through a closer look at the maturity of organizations after learning cycles based on an executive routine extrapolated to complex project innovation, or with some innovation, until reaching unambiguous repeatability (certification).

--- Maturity, learning, and productivity curves ---

Maturity translates into committed experience, the expectation that new products may be developed by the professionals involved through previous experiences (Williams 2008), effectively shortening the new project and minimizing the effort required to perform tasks that are already known, including costs and risks (Jian 2004). This translates into an exponential curve with known design (Fogliato and Anzanello 2011), albeit identifying maturity at a specific time point. The purpose is not to model learning toward achieving a specific maturity performance (Ferro et al. 2016) but to use a structure representative of the processes observed in the innovation of complex heavy construction projects as a topic of discussion.

Given the above, there is a clear effect on the decrease on the derivative of the learning curve, which stabilizes at a specific level, as indicated in the dashed curves of **Fig. 1** showing the maturity curve. The heavy civil construction industry faces challenges that are highly consolidated in the disciplines supporting its activities (for example, geometry, earthwork, paving, and drainage, among others, for roadwork), while performing numerous works worldwide, adhering to this maturity curve at a given time point (Guangshe et al. 2008).

Note that this is a photograph of the point reached through an

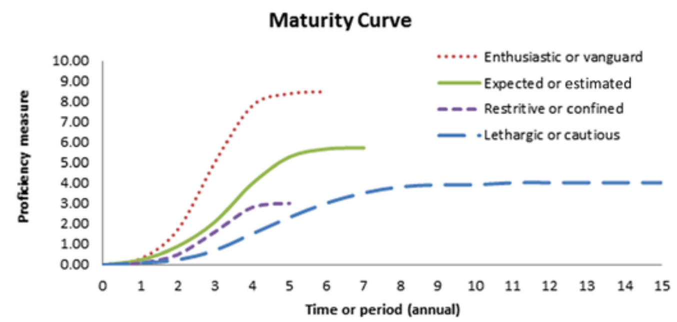

FIGURE 01. Theoretical maturity curve

effort, that is, static condition, in which projections in time typically adhere to the specificities of a given case in their history measured up to that date. The proposed theoretical situation may be observed in trends classified as follows: *(1a) enthusiastic or vanguard; (1b) expected or estimated; (1c) restrictive or confined;* and *(1d) lethargic or cautious*, benefiting from the dynamics of successive learning cycles.

Nonetheless, there is a trend to overcome this stabilization, suggesting an expected drop after reaching the new level, as shown in the classic shape of the learning curve in **Fig. 2** (Thomas et al. 1986). Thus, the state of comfort is waived toward leveraging a new condition through the inherent challenge, thereby possibly losing what had been previously achieved because of the *(2a) resistance effect* of the trend observed in the drop after the initial time point of engagement with a clear burnout, followed by *(2b) recovery and provision*. The long-term *(2c) forgetfulness effect*, which prevails in the somewhat sustained loss of the level reached, is instinctively understood. The S-shaped curve is the closest to the reality-problem in the context of complexity and innovation, based on the dynamic observation of the process, instead of a static position in the maturity curve above (Plaza et al. 2010).

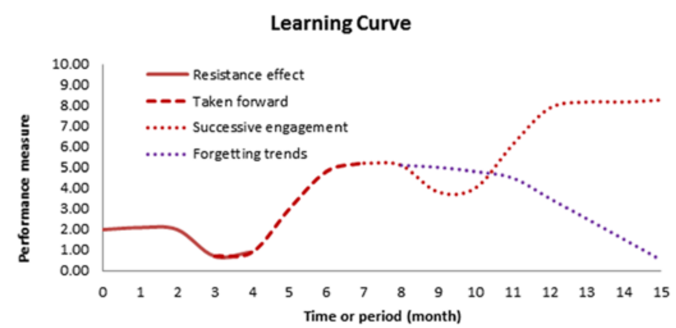

FIGURE 02. Theoretical learning (and forgetfulness) curve

This case also shows variations in rate (stronger effect on the abscissa axis) and intensity (stronger effect on the ordinate axis), typically seeking a higher level than the previous level, with any other healthy point of the *maturity curve* as long as the trend is consolidated. This condition, overlapping *(2d) subsequent engaging (or parallel engagement with multiteam systems)*, shows a staggered cadence, which is the reason for proposing compliance barriers to validate these gains before bringing them into this condition. This time point is clearly similar to gate approval, following in successive steps, as long as the minimum requirements, previously defined by quality, have been met.

The specificities and scale of the construction work project must also be analyzed when considering the resources available for the third main topic of this study, the productivity curve, as shown in **Fig. 3** (Cherrington and Towill 1983). Evidently, *(3a) experimenting* with the action of learning will make it possible to reach a given *(3b) repeatability*, managing to assess the team member, team, or company productivity after several attempts. The effects are also observed in *(3c) cost* and *(3d) risk* in the time axis when disregarding the merely theoretical scale.

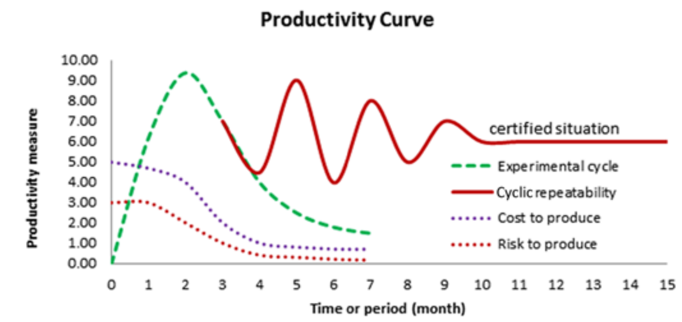

FIGURE 03. Theoretical productivity curve

Although the learning curve may show repeatability (Fioretti 2007) and is affected by two limitations, the endless interaction procedure and the quality acceptance requirement (Jaber and Guiffrida 2008), it is able to establish a specific time point to assess the issue of employability in terms of infrastructure construction, at least in single, unique projects. This is observed in heavy civil construction, which is essentially a product of site-specific work, preceded by the design of a detailed executive project. In fact, this is the case of most heavy civil construction projects, predominantly consisting of engineering-related rework. The achievement of productivity as a work goal is even hampered by the physiological barriers of its human resources, in addition to climatic constraints, risk contingency, mobilization, and preliminary auxiliary services, among others. Technological changes are combined in infrastructure engineering to condition the productive process, for example, at the construction site, using heavy machinery in clear evolution, even depending on the obsolescence or state of conservation at the required time point. Differences in software using Building Information Modeling (BIM) or similar platforms may even be found in the creative process of project design, despite the mastery of these tools by their users.

This is characterized by the use of various repetitive activities within the productive process (Suermann 2009), regarding the graphic design of the project, for example, work details, or regarding construction work, including excavation, loading, transportation, and compaction or even drainage and rail-laying services, among others. The eminently intellectual consulting engineering interface is perceived differently from contractors, whose strength is focused on machines, although they are both parts of the project.

In this casual dynamic, the theoretical curves may show trends that are somewhat different from the expected proficiency, adjusting toward facing the reality-problem. In high-pressure and hasty environments (for example, speed exceeding normality), the work scale, breadth, and complexity of activities or even the interactions formed between stakeholders may radically affect the expected trends of these curves.

Furthermore, deadline, cost and resource constraints define the scope according to normative, contractual, and legal quality standards, increasing the business risk beyond desired levels. Thus, the trends should be able to readjust to imbalances in the life cycle of projects, particularly when addressed in the portfolio. This thesis is applicable from preparations to completion, subjecting every time point to the monitoring and control issues of its management processes, inclusively affecting the pre-qualification of suppliers (Jain et al. 2014), including quality metrics, deliverables, prices, services, and other parameters that are adaptable to heavy civil construction.

--- Gate approval and auditing tools ---

Although several maturity models have already been published (Khoshgoftar and Osman 2009), the maturity necessary and sufficient to perform activities planned in the project according to their complexity, the burden of waiving the assessment cycle through continuous auditing, or the minimal use some of its critical deliverables as forward points should be analyzed from an organizational perspective. Accordingly, gate approval makes it possible to validate the executive chain, based on the Front-End Loading method, *FEL1-FEL2-FEL3*, applied to complex (Merrow 2011) or large projects, thereby allowing passage between successive stages and triggering the advance under more precise conditions, effectively minimizing risks, particularly when involving complex operations.

Treated as a business and, therefore, strategically contextualized in the organizational setting, Front-End Loading should be evaluated, selected, and prioritized within the portfolio of projects, undergoing a chain of decisions beginning with its conception (Ramos 2013). This is the classic description of the first phase, termed *FEL1*, which is invariably a high-ranking subject stipulated by very superficial indicators based on similar projects to which cost and executive deadline tolerances are applied, thereby affecting the scope. All tolerances are aligned with the business objectives based on an economic and financial viability ranging from 25% to 40% (de Moraes 2010), ensuring that only 25% of projects would be approved and having consumed only 1% of the Total Installation Cost (TIC). This assumes budgets close to Classes 4 or 5 of the Association for the Advancement of Cost Engineering International (AACEI) (Molenaar 2005), with a margin of error typically ranging from -30% to +50%, which is similar to the margin of error of publications from the Project Management Institute, ranging from -25% to 75% (PMI 2009).

Gate approval has been compared with Brazilian law, highlighting the importance of each gate but particularly the basic project concept, *FEL1*, when discussing the perspective of audit findings in contracts (Zorzal 2014). Approximately 50% of remaining projects are approved in the FEL2 phase, having consumed only 3% of TIC, within a preliminary budget corresponding to Class 3 of the AACEI, with a margin of error ranging from -15% to +30%. The remaining goes to the Project Execution Plan, which is evaluated in the FEL3, questioning again before proceeding (proceed, abort, or re-evaluate). At this phase, based on resource quotes (machines, equipment, and materials), according to the best estimates of their consumption, including the direct workforce and all other costs, it is possible to prepare the detailed budget, which corresponds to Class 2 of the AACEI, with a margin of error ranging from -5% to +15%. Approximately 2% of the projects proposed will be aborted or re-evaluated at this gate, and the cost of these projects will range from 6 % to 8% of TIC.Conversely, in the next phase, *FEL2*, engineering processes are used to support the technical feasibility of the project, effectively helping to manage work processes and advancing from the conceptual plan. Similarly, its effects are strategically aligned toward validating the business opportunity by restricting and detailing only one of the alternatives available. Inclusively, advancement to the next phase is declined when identifying marked technical-economic-financial distortions, particularly within the context of procurement management in which subcontractors have a key role in performing all or part of the tasks (Susan 2016).

This method assumes that the investment in defining the product project reduces the risks of future claims when the costs of changes are high, particularly prior, concurrent, or subsequent environmental approvals (Zorzal 2013) requiring special licenses. At least in Brazil, the basic project, that is, a project sufficiently able to outline the scope, is crucial for defining the costs based on an executive solution, including the specification of services that require resources at a given time for an approved standard quality. This has been long described in the laws of the Federal Council of Engineering, Architecture and Agronomy (Conselho Federal de Engenharia, Arquitetura e Agronomia – CONFEA) (CONFEA 2015). A high level of accuracy is often achieved, even before the *FEL3* (design process refinement), when adapting Front-End Loading to heavy civil construction. This industry already includes executive engineering at this occupational level because it uses specifications that are sufficiently detailed in their standardized tools and consolidated in the manuals and references approved by the bodies. Thus, executive proposals truly tailored to product development modeling should also be included.

Hence, this involves using execution strategies, estimates, and cost plans, which are work package items focused on defining the project execution plan (PEP). Ultimately, these actions are organized into three phases, not limited but perfectly adapted to this conceptual, basic, and executive reality, by adhering to the method in question, *FEL1-FEL2-FEL3*, discussing the critical issues that may have some impact on the objectives of this phase, predetermining the scope, time, costs, and resources according to the respective managers. If fair, the responsibilities of managers may be partly transferred to technical levels, currently assigned to the highest corporate levels with their basically economic-financial effects dramatically penalizing, if not criminalizing, their stakeholders (Karpoff et al. 2014).

Work planning has a rite of approval that is not left to chance, which is subsequently subjected to a sufficiently secure executive process, at least in theory. However, the underlying issue is the proposition that advancement between successive phases after approval unfolds through a superficial executive production process, which affects the resulting product delivered, if not well before, still during its construction.

After completing the approval process, the operation is begun, not without performing configuration adjustments when required. This is mostly unusual in heavy civil construction, except in mechanical and electrical interfaces, for example, in dams for energy generation and inter-multi-modal road-rail-port and airport terminals. Even during this phase, solutions are prescribed to minimize symptoms, whose causes are attributed to conceptual roots, often resulting in early maintenance or extraordinary adjustment procedures. This consists of using the gate to a greater extent than is commonly practiced, taking advantage of the approval action, which allows advancing to the next phase, to evaluate the maturity of its agents, without using the stringency of existing tools for the monitoring and control provided for in models of project management best practices (PMI 2008), particularly in the context of integrated change control (PMI 2009), or when using continuous audit throughout the life cycle of the project according to its maturity (Vasarhelyi et al. 2012).

The monitoring and control tools and techniques then available may apparently be used in overlapping work in the public and private sectors, particularly after the project closing phase, based on standards supported by the translated versions of the International Standards on Auditing (ISAI) and the International Standards of Supreme Audit Institutions (ISSAI) (Azuma 2008). Waiving tools, including the International Organization of Supreme Audit Institutions (INTOSAI) Guidance for Good Governance or its private counterpart (Blegvad 2007), causes collateral effects from the construction work to accounting and from accounting to investors (Uysal 2009), thereby affecting, on the one hand, accountability and, on the other hand, inevitably causing redundant capital contributions, if not profit decline, often involving fraudulent financial reporting (Graham et al. 2008).

The audit is a solution, despite the effects from the energy spent and waiting period (Munsif et al. 2012), worsened by the learning process (Mitra et al. 2015), with no return to the target activity. Unsurprisingly, the trend toward permissive advancement without a careful evaluation of practices is still much stronger than that toward sacrifice. Two case studies are analyzed below to validate the aforementioned arguments, focusing on the research method.

3. RESEARCH METHOD

The contribution of this study will be reinforced by the findings from the analysis of two specific cases through *empirical research* on the maturity curve associated with the *audit* as a process required for certification. Thus, the approach of the problem is based on qualitative bias and the critical analysis of the reality experienced by the authors. This process identifies differences in the technical compliance with gate approval toward changing the established paradigm by converging the multiple sources of evidence to then benefit from their theoretical propositions to guide data collection and analysis (Yin 2013). This is relevant for the proposed research method, case study, within a contemporary environment waiving the control of behavioral events. The aforementioned study is the methodological axis of this research.

3.1. Research questions

The following are the two research questions:

(1) How do organizations rate behavioral patterns in their learning process when they reach maturity? (2) Why should the audit be included in gate approval for timely organizational maturity certification?

--- Research proposals ---

Organizational maturity measurements are somewhat unreliable and often misrepresented in adverse learning curves, particularly at time points that represent new challenges, for example, when procuring contracts without specific experience. This is the research proposal of the present study, which is based on the permanent difficulty in choosing the correct acquisition management system.

--- Unit of analysis ---

The analysis of complex heavy civil construction work, another specific study limitation, is a determining factor for new contingencies in the production process of a single, exclusive product. Despite the repeatability of recurring activities within the production processes, they are essentially local processes; that is, the products remain in the place of their execution, which is a clearly noted counterpoint to the manufacturing industry. This is another novelty examined in learning bias. Furthermore, the samples analyzed as the reality-problem are chosen based on quotas; that is, they are representative of groups reflecting some financial order of magnitude and, therefore, differing in work scale, volume, and inherent complexity. The environmental market conditions also determine whether to waive gate approvals in these study organizations toward using the time point to show the consequences of those decisions in a fast-paced, contingency-dependent environment of opportunities.

--- The rationale connecting the data to the proposals ---

The observation was systematized and structured into five perspectives: (i) of who hires and of who is hired to (ii) design the project (product specification), (iii) manage and execute the construction work (consortium), (iv) inspect the construction work, and (v) perform the independent audit, where applicable. This was undertaken to demonstrate the intended coherence of the study objectives in two case studies, less sensitive to the replication logic (Scholz and Tietje 2002; Yin 2013). These case studies describe the gate approval time point, highlighting the responsibility of its agents through a descriptive situational analysis of the business plan with the aforementioned order of magnitude of the resources used for solutions. This would actually be the answer to the second research question because it includes the description of unforeseen theoretical categories (Eisenhardt 1989). Compliance with maturity, learning, and productivity curves is subsequently analyzed, thereby answering the first question, inferring the perspectives of organizations that use engineering resources to solve the problem.

--- Data interpretation criteria ---

This study simultaneously performs documentary research on the collection of works and projects of the authors, albeit spatiotemporally limited to the early decade and protected by trade secrecy. This process aimed to compare the findings to assuredly identify the framework of organizations in their maturity curves, according to criteria suggested by case study advocates, due to the lack of quantitative statistical significance (Yin 2013).

Their structures were analyzed in several other specific cases with similar symmetry, thereby making it possible to state procedural rigor self-sufficiency to a greater extent than that of the two case studies examined herein. Furthermore, overlooking the shift in the focus of this study, evidence shows that measurement systematization makes it possible to classify organizations into maturity levels, thereby generating future quantitative studies, albeit able to understand the structure of the phenomenon toward developing embedded hypothesis, models, and theories (Scholz and Tietje 2002).

4. CASE STUDIES

Two case studies are assessed in terms of maturity. The first addresses train station infrastructure, focusing on a drainage project that significantly affected the construction work, bringing it to a standstill (FEL3 bottleneck). The second study is a project aimed at redesigning the wastewater treatment plant of an ore terminal, with a strong environmental bias (FEL2 bottleneck).

--- Train station reality-problem ---

This rail yard, used to ship commodities worldwide, was intended for expansion, which was divided into different portfolio management projects, all interconnected to the purpose of more than doubling the distribution capacity at times of low supply of some products compared to market demand. The business plan included a strong incentive to accelerate the expected results in specialized plants, particularly in bulk storage facilities.

The budget of the project was approximately US$ 1.5 million, with US$ 300 million for construction work and services. A multidisciplinary team was hired to work on the project during the executive detailing phase, simultaneously with the construction work, costing US$ 0.1 million per month. The fast-paced work environment apparently bypassed the FEL3 gate approval, perhaps even the FEL2, which was caused and explained by the high market demand. The strategic decision to move forward with the detailing without technical validations prevented defining the scope of the basic project as early as the first drafts.

Geometric changes in the railway line were still adapting the plant layout and, therefore, returning to product concept, thereby affecting the earthworks, geodesically fixed at a given elevation, drainage, and even the railway superstructure. These changes were introduced to modernize the rail yard, which required new railroad cars, engines, and a passenger terminal, in addition to several other buildings for logistic operations, moving forward with hasty changes.

- Descriptive situational analysis of a specific problem -

For example, drainage was highlighted as a critical issue, essentially because of a design error and other remedial works, which were discussed between the building contractor and the executive management. This is an unfeasible scope, whose description is outlined in **Table 1**. Note the emphasis placed on the conceptual flaw of the drainage project outlining the geometric changes and the earthwork and material availability problems, which were overlooked in this analysis. For convenience purposes, this analysis focused on describing a single problem, which was crucial at that time, rendering its discussion irrevocable, although other issues could have been chosen.

Fig. 4 shows the landscape that determined the executive decision to stop the construction work in this stretch until a final drainage solution was found. The circle highlights an area within one kilometer of the project platform, with the main permanent line toward the harbor at the top. There, the train, still separated into pairs of cars, moves toward the roundhouse, which unloads the crude material into the conveyor belt loaders to prepare the intermediate stocks of the cargo terminal. The railway line used to return the cargo train to the mine is in on the other side. The project aimed to merge the platforms by earth-filling the floodplains in this stretch to lay down new lines that would run between and at the same elevation as the existing lines.

However, the figure highlights an earthmoving area over a water pocket, at the time overlooked by the basic engineering team, who considered it an inverted flow, requiring alternatives to move forward with the construction work, including excavating the hill that would connect the bays before entering the main water pocket, cutting off the existing culvert. This was technical solution number III. The estimated cost of this solution would be US$ 0.20 million, albeit without overcoming the difference in height to reach the receiving water. This solution was disregarded soon after.

If allowed to take its old natural path, the water would flow to the lowest areas, according to technical solution number II, which follows the water flow toward the lowest area even within the main water pocket, through a structure consisting of a simple concrete pipe culvert 1.5 m in diameter and 270.0 m in length with hydraulically sealed connections. This contingency would be less expensive than the earthmoving, then estimated at an additional cost of US$ 0.19 million. **Fig. 5** shows the bottleneck caused by engineering studies until choosing the final solution.

Geometry – duplication layout	
Existent	Extensive embankments constructed between earth-filled floodplains and small excavated hills*
Predicted	Partly merging the embankments to increase the width of the platforms throughout the train station**
Changed	Significant changes in the initial layout
Geology and geotechnics and materials	
Existent	Requirement of excavating, loading, transporting, and compacting huge earthmoving volumes
Predicted	Undersized earthmoving volumes; undersized ballast volume
Changed	Significant changes in earthmoving volumes and material used in the superstructure ballast, affecting the search for new fields or the increase of existing fields.
Hydrology and drainage	
Existent	Extensive waterways connected in massive flows to the interior of the plateaus that will be filled with earth
Predicted	Inverted flows in the designed devices, technological solution incompatible with the maintenance of the permanent route
Changed	Changes in natural and implemented flows and change in surface drainage segmentation

Notes:
*The elevation should be exactly the same throughout all rail yard lines. This safety requirement precludes trains from spontaneously rolling on the tracks.
**Existing railway lines cannot stop operating.

TABLE 01. Brief Descriptive Situation Analysis, Predictions, and Effects on Changes

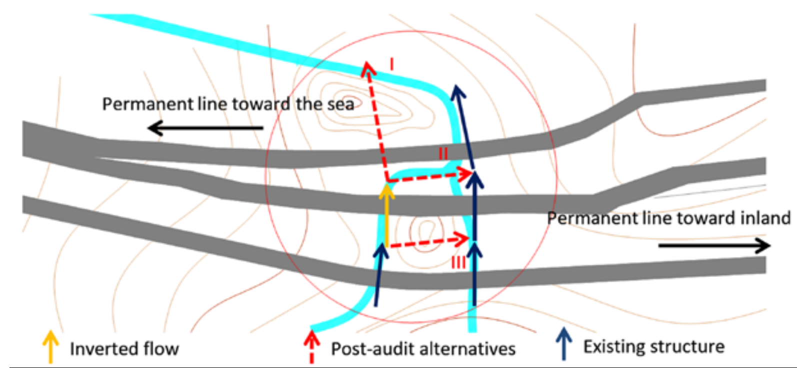

FIGURE 04. Altered floor plan and indication of its three solutions

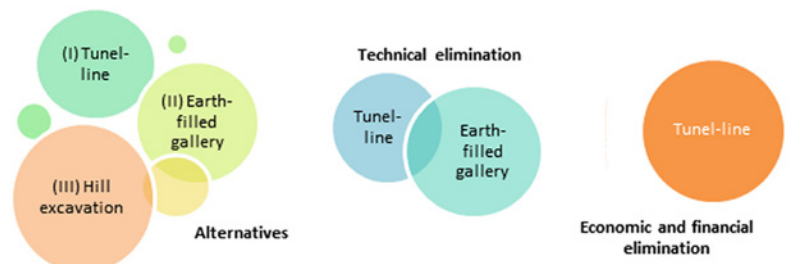

FIGURE 05. Study of alternatives and technical and economic and financial selections

Another possible solution would be to maintain the passage originally built overlying the construction of a simple, concrete pipe culvert 1.5 m in diameter and 90.0 m in length, interconnected to a 1.5 by 60.0 m tunnel-line accordingly excavated until crossing the other side of the existing embankment, in addition to inspection chambers and drainage manholes, at an additional total cost of US$ 0.15 million. At the time, this solution was then accepted for detailing, making it possible to resume the construction work after two and a half months of construction site downtime, with an estimated additional cost totaling US$ 1.45 million. In comparison, the costs of an audit would be approximately a fraction of this amount within the same timeline.

This project was under strong cost contingency and time constraints, in addition to the clear risk increase observed in this example. This contingency showed that the levels of resources involved in solutions should be made compatible with the work complexity and volume. Thus, please refer to the analysis of the different players involved in solving the problems.

--- Compliance with maturity curves ---

The contracting company is a logistics operator. Project design, or even railway construction, is not its main activity, unsurprisingly outsourcing rather than maintaining engineering staff to support the target activity. Thus, this company may be characterized in the maturity curve by a *(1d) lethargic or cautious* behavior, uninterruptedly accumulated over years of operation.

This company acquires specialized services when seeking to invest in its industrial park. The project design and construction management companies, both contractors, are expected to initially work within their specialty, each with its role, using the notation *(1b) expected or estimated*. The designer of the basic project, which was developed at an apparently normal pace, used a company that develops products with all types of failures, not only the specific issue reported. Thus, the project design company may be characterized under a *(1c) restrictive or confined* notation, based on the outcome. However, the case had a negative effect on the project, affecting the solutions subsequently proposed in a high-pressure environment with tight deadlines, accelerating new actions, if not deferring problems.

For this purpose, the company sought optimization solutions, not only to avoid successive delays in the work queue but also to recover costs and meet deadlines. Given the scope of the work, even the consulting company lacked all these human resources, searching for strategic partners in the market for out-tasking or acquiring joint ventures, considering the medium-term prospects (compliance with other contracts). In a high-demand market, such resources could be easily acquired by raising prices, particularly for the qualified workforce. Then, such engagement occurs in the second branch of the learning curve *(1a) enthusiastic or vanguard*, inclusively requiring addressing the inspection company, typically outsourced and often the same company that designs the project, all shown in **Fig. 6**.

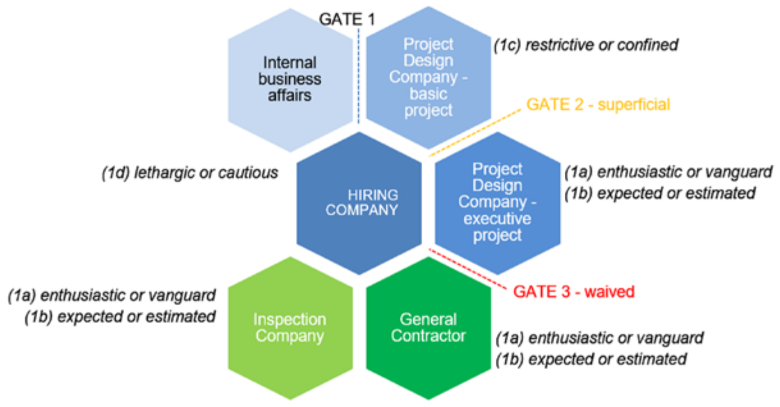

FIGURE 06. Maturity analysis according to the specific case study

Based on the knowledge of its human resources, and not only in this case, the solution is limited by a technological plus, which permeates the construction work and fits similar curves. Specialized companies were then invited to provide services for the tunnel-line construction; that is, the solution developed, operating in the curve branch *(1a) enthusiastic or vanguard*, whereas the general contractor *was operating in the (1b) expected or estimated branch*.

--- Compliance with learning and productivity curves ---

Thus, note that the companies are located in different cities, miles apart from each other, sharing only the construction site and requiring a tremendous integration effort. Any solution without the approval of the stakeholders was insufficient because it would immediately be overseen by the general contractor (construction consortium), the inspection company, and several departments of the hiring company, not only safety and the environment but also operation and maintenance of the logistics platform.

The learning curve markedly decreased in its initial phase, causing a sharp drop in productivity and consuming the energy of its resources to overcome daily challenges, without compromising the deadlines. This process was experienced by the agents in their respective roles in the construction site. **Fig. 7** shows a theoretical comparison between the design processes simultaneous with the detailing and execution of the work, somewhat changing the

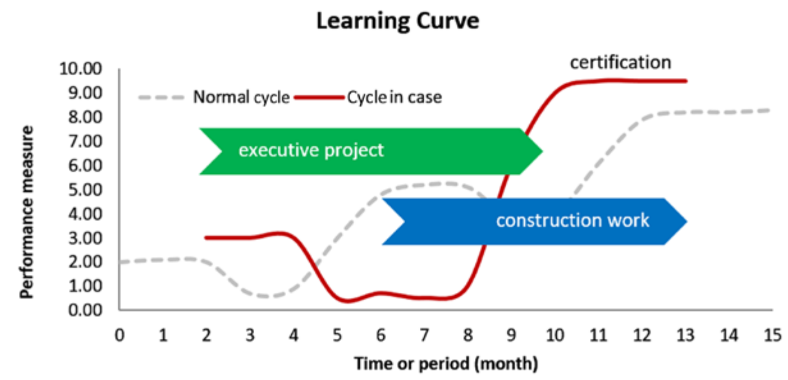

FIGURE 07. Extensive effect of the lack of gate approval on the learning curve

learning and productivity curve patterns.

The learning and productivity curves remained low for a prolonged period of time until the specific problems were solved and gate approval was achieved, consuming a tremendous amount of resources to leverage the curve to the new point ending this phase. Such stress refers to the *(2a) resistance effect* of the logarithmic decrease after the initial time point of engagement with a clear burnout, followed by *(2b) recovery and provision*, stabilizing the maturity level reached. Change control was somewhat precarious, thereby limiting recording during the lessons learned, favoring the *(2c) forgetfulness effect*. Nevertheless, these routines are most unlikely to be repeated in a short period of time because this was a complex project in a markedly fast-paced work environment, thereby attenuating the effect, despite the lack of historical records.

At this time, the ascendant noticeably results from an increase in resources, often with three work shifts, even in the project design and detailing (the intellectual part of the work), alongside the machine operations performing the infrastructure construction work itself (manual work), both under repetitive notation. Similarly, executive project operations during the construction work were noticeably performed in the ascending branch of the productivity curve, still in its *(3a) experimental cycle*. Therefore, *(3c) costs and (3d) risks* were at their peak. Simultaneous operations were almost confused with the commissioning of the new line, and even the existing line maintenance processes were gradually incorporated into the new

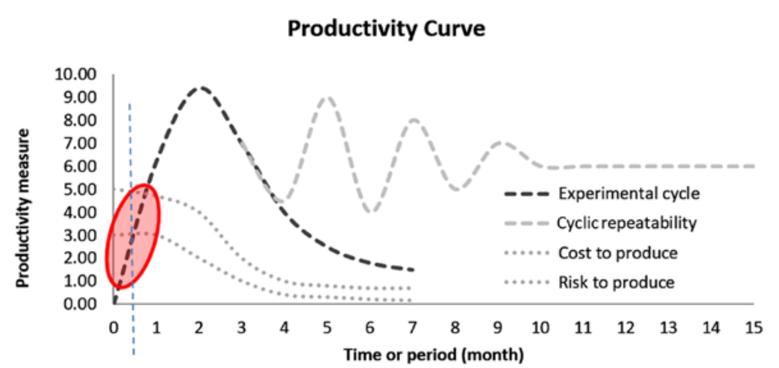

FIGURE 08. Early effect of the lack of gate approval on the productivity curve

line under construction. There was also the effect of the short period between the delivery and approval of the executive project and the subsequent service order, whose weight was heightened by stakeholders on the scene. Nonetheless, the suppliers were evaluated with scores conducive to pre-qualification in future contractor bids.

Please refer to the initial time point in **Fig. 8.**

In this environment of extreme pressure, decisions were prone to waste and rework when realizing the unfeasibility of the solutions. Productivity also noticeably ranged significantly because only the service orders were given separately, masked by the normal and uninterrupted traffic. In this case, the level was certified by the success of the work delivered months before the deadline, despite exceeding the budget.

A new point in the curve is reset for all players, at a higher level than their initial point, based on the analysis of the maturity reached. They would all be equally subject to forgetfulness because this was a large and complex project, unlikely to be repeated in the short term. In fact, this was shown by the temporality of the players, some of whom spanned two generations of engineering, an unusual meeting between senior, middle, and junior positions, each stamping their mark in the work performed. In Brazil, projects of this magnitude are only performed almost every 40 years, which was a reality shock for its participants. This was a challenge for the younger staff members, knowledgeable in the latest technology, in contrast to the professional experience of the senior staff, including permanent staff engineers and technicians. This dialogue should be noted in this section.

---Reality-problem of the cargo terminal ---

This is another logistics operation platform, completely unrelated to the previous case, particularly the topic, which is closer to environmental issues. This is a water reuse system for rainwater containing dispersed and dissolved materials, including heavy metals. The existing system had an obsolete design and was operating without treatment efficiency, ultimately releasing the waters into the cove next to the port and requiring a change in stock materials, which were the reasons for the investment.

The development project was budgeted at approximately US$ 0.1 million for project design and US$ 4 million for construction work. A specialized team was hired for the executive detailing phase, pending approval by an independent auditing company hired to validate the basic project at the approximate cost of US$ 6 thousand for two months of work.

In contrast to the previous case, this project followed the standard gate approval process, carefully observing the methodological steps because a specialized company was hired to differentiate the work completed and delivered for detailing, which is a FEL2 validation. The audit was maintained outside the sphere of influence of stakeholders, albeit with full access to the documents, field, and even all informants: the hiring company, the consulting company that designed the basic project, in this case, different from the company that designed the executive project, and the general contractor, which supervised the basic project at the time.

- Situational-descriptive analysis of a set of problems -

The scope of the development project was to adapt the rainwater harvesting and treatment system for reuse in the storage area. Despite numerous interferences, the premise of a shorter transport route to the treatment system was one of the critical issues of the development project.

Within the future FEL2, the auditing review began with a set of interviews conducted with the existing plant operational and maintenance staff on the inventory of installed equipment, procedural routines, and their workforce and input requirements. Furthermore, the wastewater characterization and the outlook supporting the engineering project for the crude, intermediate, and final wastewater treatment process proposed as a solution were also subjected to validation.

The auditing terms required understanding the technical literature of the models suggested in the conceptual and basic proposals, in addition to validating the data collection introducing the treatability studies suggested as engineering routes. There were six treatability studies in total, with guidelines on the processes to be maintained or changed in the existing system. The detailed audit included information from graphic design in Autocad, through textual elements of the sizing calculation memories and explanations to the input data presented as evidence of pertinent hydrological, hydraulic, and sanitary modeling work completion. The audit not only included document analysis but also their checking in the field, particularly assessing interferences, in addition to construction methods and their consequences for the uninterrupted operations of the industrial site Thus, note that this was not merely checking chores but closely monitoring what had been produced in the construction works up to that point.

They were all regulated in the conceptual project, which reformulated the lack of any pre-treatment, sediment control in the rainwater harvesting channels, lung reservoir to level the rainfall regimes at a minimum 10-year recurrence, and treatment regimen with 5 years of data. The conceptual project also considered the inefficiency of clogged decanters and without a draining and bottom-cleaning schedule, in addition to inefficient, low-rate filters and backwashing systems, among others.

Rainwater catchment tanks, mechanical decanters, the interface with specialized water treatment tank, the installation of diffusers, flowrate measurement and control gates, backwashing automation, the dosing of chemicals, and self-cleaning of the line were required. These solutions were characterized within the processes partly shown in **Fig. 9**, which were subjected to gate approval.

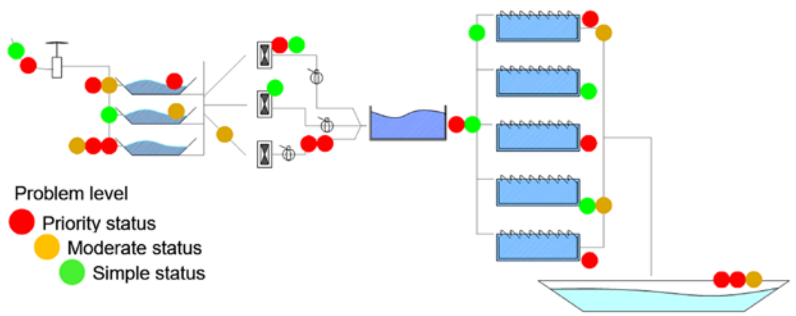

FIGURE 09. Partial flowchart of equipment audited with critical issues

The audit assessed the exposed circuits to validation, ultimately failing them. Their problems were classified into three levels in each subsystem, as shown in **Fig. 10**, summarizing the audit conclusion, recommending the inevitable path correction, addressing several points, still in the concept, thereby motivating the decision to prevent the business from moving forward to the next step of executive detailing.

The *priority status* had been defined as the status definitely precluding executing the construction work, for example, flow inversion in projected channels with the wrong slope, an error still unresolved, which would inevitably lead to failure. The *moderate status* has that repercussion to some extent, albeit with the possibility of solving the problem, depending on the availability of space and the absence of other critical issues.

Finally, any failure in the graphic design of the planks, overlap or absence of parts, flows and devices, among others, which would not preclude the project and could easily be fixed, would be classified with *simple status*.

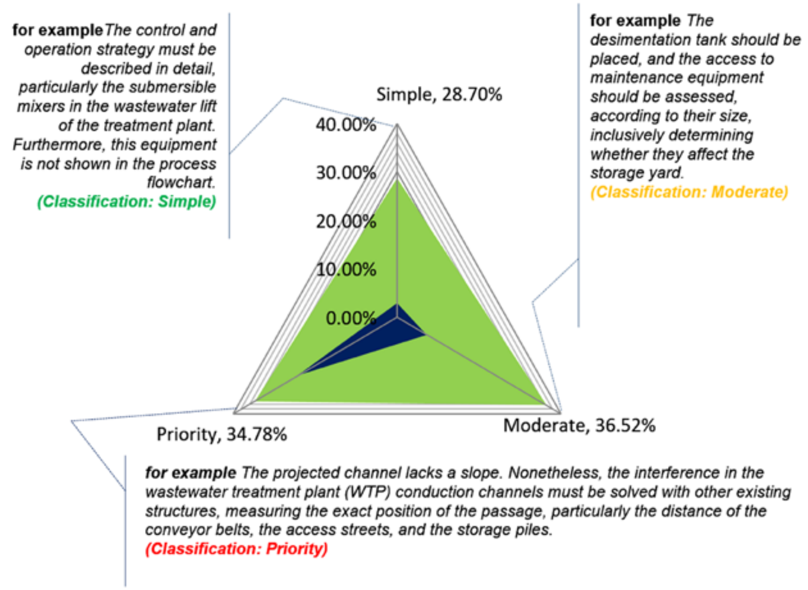

FIGURE 10. Critical corrections for project approval

After the review, the problems ranked by priority, based on their distance from reasonableness, a sui generis case, accounted for nearly one-third of the findings indicated in the conformity audit, showing the evidence in the paperwork of the auditors. This would raise the tone of the conversation in the audit report meeting, which is shown when removing the same effect of the risk between the equilateral triangle classes and highlighting a 1:2:7 weighing ratio projected on the *priority status* over others in **Fig. 10**. The confidence interval of this classification was 2.6 percentage points, with over 170 findings. This classification was approved by a simple majority based on the experience of the audit team and after consulting with the technicians.

Consequently, the likelihood of success in the future decision-making processes of stakeholders increased significantly, inclusively achieving contractor accountability and cuts in measures, preventing fixed-term contracts and reformulating strategies for the treatment unit with a new business plan. These procedures re-entered the business priority queue, requiring a new strategic decision cycle until its execution, dramatically changing the scope.

This typifies auditing as a crucial element for investments that would otherwise be prone to failure, eventually wasting money on environmental credit lines and potential environmental damage and sanctions resulting from an inefficient wastewater treatment system. Unlike the previous case, the costs of failing to perform the audit at the gate cannot be estimated because no funds were actually spent in construction errors, although their existence is undeniable.

--- Compliance with maturity curves ---

Although the deliverable subjected to approval failed to convince the audit of having achieved its purpose, all companies involved were operating under normal conditions, according to the predicted schedule and budget. This reason suffices to remove either the company responsible for the basic project from its maturity level, which would then be behind the expected maturity curve, in a condition near the *(1c) restrictive or confined* branch.

The hiring company is at another level. This company would be classified into the *(1d) lethargic or cautious* branch because of its specialty and operational and maintenance paralysis, similar to the previous case. The audit firm is at the *(1a) enthusiastic or vanguard* branch because of its expertise and remarkable knowledge, whereas the managing company, which abstained from making considerations to mediate the issue within the stakeholders, accounts for the *(1b) expected or estimated* branch.

- Compliance with the learning and productivity curves -

The learning analysis shows that the conceptual and basic project was designed as predicted in the portfolio management process, which decided to remove the project from the list of priorities because the project was submitted to audit, thereby preventing the transition to the next gate. This shows a change in control for the players of the process, placing the control release at a more likely point within the logarithmic decrease due to the *(2a) resistance effect* following the engagement with a clear burnout. Unlike the previous case, no *(2b) recovery and provision* occurred in this case, although the process was recorded as a lesson learned due to the audit phase, particularly considering the litigation, discouraging *(2c) forgetfulness*.

The project design company was apparently *(3a) experiencing* the learning action of what had been sacrificed in the process. Conversely, from the perspective of the audit firm, this was another routine case, which may benefit from the *(3b) repeatability* of its experience by using its certification standards. The former operated early in the *(3c) cost* and *(3d) risk* curves, whereas the latter had room for maneuver in both channels. Similar to the previous case, all suppliers in the second case were rated with scores conducive to pre-qualification for future contractor bids, at least throughout the creative product design process. Then, in a counter-claim, they could be sued.

5. CONCLUSIONS AND FINAL CONSIDERATIONS

The paradigms of quality system certifications are still focused on the previous monitoring and control tools, concurrent and subsequent to processes in their different phases (Franceschini et al. 2011). However, their terms are not confused with this cautionary and strategic analysis (Abbaszadegan 2016). The use of checklists of deliverables based on somewhat superficial key characteristics that weaken the process experienced, particularly when organized into a production line rather than circularized, is insufficient.

Thus, the present study illuminates the maturity of agents synergistically forming the teams of an organization and what their deliverable product would be. Would the product be sufficiently mature to be taken to the construction site? Alternatively, were the organizations involved able to turn it into a product? The act of retaining the expertise of project participants must be re-discussed in the hiring plan. This is commonly observed among those who hire based on testimonials, often without experience, that is, without certification.

This experience shows that the numbers are insufficiently assessed with concrete evidence of experience, often failing to question the auditing process and merely proposing liquidation. This is primarily rooted in the permissiveness of authorizing poorly designed projects. Prominent uncertainty is counteracted with caution, then considering the audit a necessary evil, re-analyzing the indirect added value, at least, regarding the decision-making process. Audits are based on evidence, documents supporting the findings, and they substantiate claims (Becerik 2006), inclusively affecting accountability.

Thus, larger complex projects or projects involving some type of innovation are susceptible to misfortune, increasing the risks of measurements performed many times that disregard their initial forecasts (Leslie 1997). This learning is tested in each new challenge, gradually changing the theoretical curve of each player in this analysis through certification by auditing tools.

Thus, the behavior of stakeholders may be described according to their maturity, learning, and productivity, based on theoretical curves, mimicking the pragmatism shown in the present analysis of two case studies designed to meet the study objectives by answering the research questions. Certification now defines the level reached by each stakeholder, partly or fully, suggesting future paths in new projects.

The depth of the audit proposed herein as a systematic approach is such that, if used in the context of gate approval, it should then make it possible to meet the accounting, financial, and economic goals, significantly encouraging the decision-making process toward improving the business through a managerial and administrative contingency approach. This auditing approach seeks to renew the manner in which companies, particularly publicly traded companies, report their balance sheets to the public.

Conversely, the result from the audit engagement is perceived as a short-term and low-cost extra effort, albeit significantly affecting the success of the project by cutting surplus costs and minimizing risks or rethinking the scope object to the required depth. Indeed, the portfolio leveraged with this type of managerial approach tends to minimize planning failures in a broader process of quality certification, using more specialized monitoring and control tools (Hoelscher 2013).

However, is it possible to apply these conclusions to any case? Well, this study is limited because it addresses two situations in the context of heavy civil construction, covering renovation and duplication construction, according to a pragmatic analysis of the reality-problem through exploratory research. Similar to these cases albeit not limited to them, the conclusions may be applied to complex construction projects, with a broad effect on current portfolios.

The benefits from this proposal go beyond the project because they translate into a clear risk and cost contingency, affecting the equity value of a company, maximizing its assets or, conversely, minimizing its own and third-party liabilities, particularly when they contribute to the trust (distrust) of investors. In times of transparency, standardizing the *audit as a tool for project maturity certification in heavy civil construction* is timely. ◆

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• REFERENCES •

Abbaszadegan, A. (2016). "Instantaneous project controls: Current status, state of the art, benefits, and strategies." Doctoral Thesis, Arizona State University, Tempe, AZ.

Andersen, E. S., and Jessen, S. A. (2003). "Project maturity in organisations." Int. J. Proj. Manag., 21(6), 457-461.

Anzanello, M. J., and Fogliatto, F. S. (2011). "Learning curve models and applications: Literature review and research directions." Int. J. Ind. Ergon., 41(5), 573-583.

Azuma, N. (2008). "The framework of INTOSAI Government Auditing Standards: in the stream of international convergence." Gov. Audit. Rev. Japão Tóquio, 15, 77-97.

Becerik, B. (2006). "Implementation and value of online collaboration and project management systems in design and construction." Doctoral Thesis, Harvard Graduate School of Design, Cambridge, MA.

Blegvad, K. (2007). "INTOSAI's new professional standards framework." Int. J. Gov. Audit., 34(4), 11.

Cherrington, J., and Towill, D. (1983). "Productivity control via learning curve models." Int. J. Prod. Res., 21(3), 337-346.

CMMI Product Team (2010). "Improving processes for developing better products and services, CMMI R G for Development." Version 1.3. Technical report, Carnegie Mellon University, Pittsburgh.

CONFEA (2015). "Conceitua o termo Projeto e define suas tipificações." DOU 23/04/15, Brasília, DF, 2.

de Moraes, F. R. G. (2010). "Constribuição ao estudo da concepção de projetos de capital em mega empreendimentos." Master's Thesis, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil.

Eisenhardt, K. M. (1989). "Building theories from case study research." Acad. Manag. Rev., 14(4), 532-550.

Ferro, M. V., Bilbao, V. M. D., and Pena, F. J. R. (2016). "Modeling of learning curves with applications to pos tagging." Comput. Speech Lang., 41, 1-28.

Fioretti, G. (2007). "The organizational learning curve." Eur. J. Oper. Res., 177(3), 1375-1384.

Fogliato, F. S., and Anzanello, M. J. (2011). "Learning curve: The state of the art and research directions." Learning curves: Theory, models and applications, M. Y. Jaber, ed., CRC Press, Boca Raton, FL, 3-21.

Franceschini, F., Galetto, M., Maisano, D., and Mastrogiacomo, L. (2011). "A proposal of a new paradigm for national quality certification systems." Int. J. Qual. Reliab. Manag., 28(4), 364-382.

Graham, J. R., Li, S., and Qiu, J. (2008). "Corporate misreporting and bank loan contracting." J. Financial Econ., 89(1), 44-61.

Grosse, E. H., Glock, C. H., and Müller, S. (2015). "Production economics and the learning curve: A meta-analysis." Int. J. Prod. Econ., 170, 401-412.

Guangshe, J., Li, C., Jianguo, C., Shuisen, Z., and Jin, W. (2008). "Application of organizational project management maturity model (OPM3) to construction in China: An empirical study." Proc., 2008 Int. Conf. on Information Management, Innovation Management and Industrial Engineering, IEEE, Piscataway, NJ, 56-62.

Hobday, M. (2000). "The project-based organisation: an ideal form for managing complex products and systems?" Res. Policy, 29(7), 871-893.

Hoelscher, J. L. (2013). "Differential determinants and effects of audit quality." Thesis, University of Nebraska - Lincoln, Lincoln, NE.

Huber, G. P. (1991). "Organizational learning: The contributing processes and the literatures." Organ. Sci., 2(1), 88-115.

Jaber, M. Y., and Guiffrida, A. L. (2008). "Learning curves for imperfect production processes with reworks and process restoration interruptions." Eur. J. Oper. Res., 189(1), 93-104.

Jain, R., Singh, A. R., Yadav, H. C., and Mishra, P. K. (2014). "Using data mining synergies for evaluating criteria at pre-qualification stage of supplier selection." J. Intell. Manuf., 25(1), 165-175.

Jian, J.-Y. (2004). "An analysis and theoretical development of mental learning curves." Doctoral Thesis, Texas Tech University, Lubbock, TX.

Karpoff, J. M., Lee, D. S., and Martin, G. S. (2014). "The consequences to managers for financial misrepresentation." Accounting and regulation: New insigts on governance, markets and institutions, R. Di Pietra, S. McLeay, and J. Ronen, eds., Springer, New York, 339-375.

Khoshgoftar, M., and Osman, O. (2009). "Comparison of maturity models." Proc., 2nd IEEE Int. Conf. on Computer Science and Information Technology, IEEE, Piscataway, NJ, 297-301.

Leslie, S. E. (1997). "Forecasting the funding needs of infrastructure renewal: A construction estimating technique." Thesis, University of Cincinnati, Cincinnati.

Malerba, F. (1992). "Learning by firms and incremental technical change." Econ. J., 102(413), 845-859.

Merrow, E. W. (2011). Industrial megaprojects, Wiley, Hoboken, NJ.

Meyer, J. W., and Rowan, B. (1977). "Institutionalized organizations: Formal structure as myth and ceremony." Am. J. Sociol., 83(2), 340-363.

Mitra, S., Song, H., and Yang, J. S. (2015). "The effect of Auditing Standard No. 5 on audit report lags." Account. Horizons, 29(3), 507-527.

Molenaar, K. R. (2005). "Programmatic cost risk analysis for highway megaprojects." J. Constr. Eng. Manag., 10.1061/(ASCE)0733-9364(2005)131:3(343), 343-353.

Munsif, V., Raghunandan, K., and Rama, D. V. (2012). "Internal control reporting and audit report lags: Further evidence." Audit. J. Pract. Theory, 31(3), 203-218.

Plaza, M., Ngwenyama, O. K., and Rohlf, K. (2010). "A comparative analysis of learning curves: Implications for new technology implementation management." Eur. J. Oper. Res., 200(2), 518-528.

PMI (2008). "A guide to the project management body of knowledge." Project Management Institute, Newtown Square, PA, 507.

PMI (2009). "A guide to the project management body of knowledge." Project Management Institute, Newtown Square, PA, 507.

PMI (2013). Organizational project management maturity model (OPM3): Knowledge foundation, PMI, Newtown Square, PA.

Ramos, W. J. (2013). "Aplicação de VIPS em Projetos de Capital." Mundo Project Management, 51, 52-55.

Salem, O., Solomon, J., Genaidy, A., and Minkarah, I. (2006). "Lean construction: From theory to implementation." J. Manag. Eng., 10.1061/(ASCE)0742-597X(2006)22:4(168), 168-175.

Scholz, R. W., and Tietje, O. (2002). Embedded case study methods: Integrating quantitative and qualitative knowledge, Sage, Thousand Oaks, CA.

Suermann, P. C. (2009). "Evaluating the impact of building information modeling (BIM) on construction." Doctoral Thesis, University of Florida, Gainesville, FL.

Susan, P. (2016). "Third-party risk management: Moving up the maturity curve." RMA J., 98(8), 36-40.

Thomas, H. R., Mathews, C. T., and Ward, J. G. (1986). "Learning curve models of construction productivity." J. Constr. Eng. Manag., 10.1061/(ASCE)0733-9364(1986)112:2(245), 245-258.

Uysal, P. (2009). "Essays in macroeconomics." Doctoral Thesis, Boston College, Boston.

Vasarhelyi, M. A., Alles, M., Kuenkaikaew, S., and Littley, J. (2012). "The acceptance and adoption of continuous auditing by internal auditors: A micro analysis." Int. J. Account. Inf. Syst., 13(3), 267-281.

Williams, T. (2008). "How do organizations learn lessons from projects—And do they?" IEEE Trans. Eng. Manag., 55(2), 248-266.

Wolters Kluwer (2013). "TeamMate internal audit technology survey results now available." Manufacturing Close-Up. May 16.

Yin, R. K. (2013). Case study research: Design and methods, Sage, Thousand Oaks, CA.

Zorzal, F. M. B. (2013). Gerência ambiental: Resumo de experiências de gestão ambiental aplicadas à industria e a cidade pelas referências do PMBOK, PACO, São Paulo.

Zorzal, F. M. B. (2014). Gerência de Contratos: Propostas técnicas para licitações públicas e privadas, PACO, São Paulo.