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RCMOS - Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VII, v.1 2026 | Submission: 08/25/2026 | Accepted: 08/28/2026 | Publication: 08/31/2026

Managing project changes in large-scale construction projects: impacts on planning, measurement, and cost control.

Project change management in large-scale works: impacts on planning, measurement and cost control

Project change management in large-scale works: impacts on planning, measurement and cost control

Mariangela Regina da Silva Sampaio de Souza1

ABSTRACT

Large-scale projects are characterized by high technical complexity, long execution cycles, and strong interdependence between design disciplines, making them especially vulnerable to changes that occur after the start of execution. This article aims to analyze, from the technical perspective of cost engineering and project management, how design changes occurring during the execution phase influence the planning, measurement, and control of contractual costs in large-scale projects. It begins by problematizing how such changes impact schedules, costs, and contractual measurement, with a specific focus on the Design Change Notification (DCT) instrument, field documentation, information traceability, additional services, and contractual control as a whole. Methodologically, the work consists of bibliographic and documentary research, of a qualitative and exploratory-descriptive nature, based on the literature on planning and control of works, relevant technical standards, and engineering contract legislation. The results indicate that the absence of a structured change management workflow compromises the traceability of field decisions, generates discrepancies between measured and planned quantities, causes cascading schedule deviations, and weakens the technical defense of claims for economic and financial rebalancing.

As a contribution, a change management workflow structured around the NAP (New Approval Procedure) is proposed, linked to control indicators and routines for photographic documentation, daily work reports, and measurement bulletins, capable of reducing information asymmetry between the contracting party and the contractor and providing greater governance to the contract amendment process.
Keywords: Project change management. Project Change Notification (PCN).
Contractual measurement. Cost control. Document traceability. Large-scale projects.

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[1] **About the Author:** Mariangela Regina da Silva Sampaio de Souza is a civil engineer with over 15 years of experience in...

large-scale projects in the civil construction, steel, infrastructure, and mining sectors. Throughout its history.

Throughout his professional career, he has consolidated expertise in planning and controlling construction projects, physical and financial management, and measurements.

Budgeting, contract analysis, earthworks, drainage, retaining walls and infrastructure, participating in developed projects.

for major industrial and mining groups, such as Gerdau, Vallourec & Sumitomo, CSN, and Vale. Its performance distinguishes itself...

whether through the integration of technical field knowledge and strategic project management, including cost control,

Monitoring schedules, analyzing project changes, preparing technical documentation, and interfacing with...

Multidisciplinary teams, clients, and managers. Also experienced in leading and training professionals.

Mariangela has built a career marked by the continuous evolution from technical roles to higher positions.

Responsibility in planning and managing complex projects, combining solid practical experience and training.

in Civil Engineering.

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ABSTRACT

Large-scale construction projects are characterized by high technical complexity, long execution cycles and strong interdependence among design disciplines, which makes them particularly vulnerable to changes occurring after execution has begun. This article aims to analyze, from a technical engineering-cost and project-management perspective, how design changes that occur during the execution phase influence scheduling, cost and contractual measurements in large construction projects. The study addresses how such changes affect deadlines, costs and contractual measurement, focusing specifically on Design Change Notices (NAP), field documentation, traceability, additional services and contractual control.

Methodologically, the work is based on bibliographic and documentary research, of a qualitative and exploratory-descriptive nature, grounded in the literature on construction planning and control, relevant technical standards and engineering-contract legislation. The results indicate that the absence of a structured change-management workflow compromises the traceability of field decisions, generates divergences between measured and planned quantities, causes schedule deviations through ripple effects, and weakens the technical defense of economic-financial rebalancing claims. As a contribution, the article proposes a change-management workflow structured around the NAP, linked to control indicators and to photographic documentation, daily work reports (RDO) and measurement bulletins, capable of reducing information asymmetry between owner and contractor and providing greater governance to the contract-amendment process.
Keywords: Design change management. Design Change Notice (NAP). Contractual measurement. Cost control. Documentary traceability. Large-scale construction projects.

INTRODUCTION

Large-scale projects in heavy civil construction and industry — such as power plants, industrial plants, transport infrastructure units, dams, hospital complexes and highly complex buildings — are, by nature, long-term projects, high contractual value and multiple technical interfaces between civil engineering disciplines, Electrical, hydraulic, mechanical, instrumentation, and automation. This inherent complexity makes with which the detailed design, however detailed it may be in the bidding or contracting phase, It is unlikely to remain unchanged throughout the entire execution of the work. Interferences not mapped, incompatibilities between disciplines, scope changes requested by contractor, technological evolution, licensing requirements and field conditions Factors that differ from those foreseen in the basic design constitute recurring reasons for project alteration. during execution.

Managing these changes is not merely an administrative activity: it has direct impact on three central variables in project control — the timeframe contractual, the cost of the undertaking and the measurement of the services performed. When a If a project change is not properly identified, formalized, and tracked, the effects They tend to spread silently along the planning chain, compromising

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The accuracy of the physical-financial schedule, generating discrepancies between the quantities.

discrepancies between what was stipulated in the contract and what was actually executed on the field, weakening the technical defense.

of any potential claims for economic and financial rebalancing before the contracting party, bodies of control or arbitration instances.

In this context, formal change control instruments become relevant, of which The Project Change Notification (NAP) stands out — also referred to in some Organizations such as Project Change Notification/Project Change Note, Field Change Notice (FCN) or Design Change Notice (DCN), according to the nomenclature adopted by contractor. The purpose of NAP is to record, in a standardized, formal and dated manner, all Project changes identified in the field or in the office, allowing for traceability of the technical decision, measurement of its impacts in terms of time and cost, and linking the change to Supporting documentation — daily occurrence log (DOL), sketches, reports of Calculations, measurement reports, and photographic evidence.

Given the above, the research problem guiding this article can be stated as follows: such as design changes that occur during the execution of large-scale projects. They influence the contract term, the cost of the project, and the contractual measurement of services. executed? Similarly, the extent to which the existence—or absence— from a structured change management workflow, supported by tools such as NAP, the Field documentation and document traceability can mitigate the risks of diversion. due to the timeframe, cost, and measurement inherent to this type of undertaking.

The overall objective of this work is to analyze, from the technical perspective of cost engineering and... Project management, the process of managing project changes in large-scale construction projects. Size and its impacts on the planning, measurement, and control of contractual costs. How specific objectives, the aim is to: (i) systematize, based on technical and normative literature, the Project change concepts, NAP, field documentation, traceability, and services. additional; (ii) discuss the mechanisms by which design changes affect the (iii) discuss the physical schedule and the productivity of the execution teams; through which project changes impact contractual measurement and control of costs, including contractual addenda and economic-financial rebalancing; and (iv) propose a change management workflow, structured around NAP and control indicators, Applicable to large-scale projects.

The relevance of the topic is justified on two levels. On the technical-operational level, the experience Consolidated experience in the management of large projects demonstrates that a significant portion of

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Deviations in schedule and cost in complex projects do not stem from execution flaws.
properly speaking, but rather changes in scope and design that were inadequately managed, whose
The effects only become visible once they are already consolidated in the schedule and measurement.
contractual and governance plan, the lack of documentary traceability of changes
This weakens the contractor so much that they lose control over what was actually done.
altered and why — regarding the contractor, who tends to face difficulties in proving,
In the face of audits and control bodies, the causal link between the project alteration, the
Additional service performed and the corresponding impact on time and cost.
This article is limited to the analysis of large-scale projects contracted under the regime of
contract, with periodic measurement for services performed, context in which the formalization
Changes made through NAP and the traceability of field documentation take on a role.
central to the defense of contractual claims. It is not the objective of this work to exhaust the discussions.
relating to EPC (Engineering, Procurement and Construction) contracts under a lump sum price,
nor to the particularities of each legal regime for public or private contracting, which
They are mentioned only insofar as they illuminate the central discussion on management.
changes.
Regarding the structure, in addition to this introduction, the article is organized into eight sections. Section 2
It presents the theoretical framework, addressing the planning and control of large-scale construction projects.
the concept and classification of design changes, the NAP, field documentation and the
Traceability, additional services and contractual addenda, and contractual measurement. Section 3
describes the methodological procedures adopted. Sections 4 and 5 discuss,
respectively, the impacts of design changes on planning and on measurement.
and cost control. Section 6 proposes a structured change management workflow. The section
7 presents an applied, illustrative discussion on the operationalization of the flow.
proposed. Finally, section 8 presents the final considerations, followed by the references.

THEORETICAL FRAMEWORK

Planning and control of large-scale construction projects.

The planning of large-scale projects can be understood, from Mattos' perspective.
(2010), as the process of defining in advance the activities necessary for the execution of
undertaking, its deadlines, resources and logical sequencing, materialized in

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instruments such as the physical-financial schedule, the work breakdown structure (WBS), and the The S-curve of physical and financial progress. Limmer (1997) reinforces that planning should not be understood not as a unique event, situated only at the beginning of the undertaking, but as a process. continuous, fed back by information produced throughout the execution — among which The following stand out: measurement data, field records, and occurrences that imply... Scope change.

Control, in turn, constitutes the counterpart to planning: it consists of comparison. A systematic comparison between what was planned and what was actually achieved, with a view to the timely identification of deviations and to... Adoption of corrective actions. In large-scale projects, control is exercised in multiple ways. simultaneous fronts — physical (progress of services), financial (costs incurred and measurements), contractual (addendums, adjustments, rebalancing) and quality-related—so that the integrity of The information that feeds these controls is a necessary condition for their effectiveness. When Design changes occur without proper formal documentation, the database that supports the Control begins to diverge from the reality of what is being implemented, compromising both the planning and the execution. remaining regarding the project's performance analysis.

Integrated change control is treated by the Project Management Institute as part of essential aspects of project governance, involving the analysis of change requests, the assessment of its impacts, the formal decision and the controlled updating of the baselines and of project documents (Project Management Institute, 2017). This logic — identifying the Change, evaluate its effects, submit it to deliberation, and only then incorporate it. formally related to the project — it is directly applicable to managing changes in large-scale construction projects. Size. In addition, ISO 21502:2020 reinforces the need for control practices. consistent with the context, complexity and life cycle of the project (International Organization for Standardization, 2020).

In large-scale projects, the interdependence between design disciplines—civil, structural metal, piping, electrical, instrumentation — causes a specific change, seemingly localized, it tends to produce chain effects on subsequent activities and on related disciplines. This phenomenon, discussed in the international literature as ripple The cascading effect (Ibbs; Nguyen; Lee, 2007) is particularly relevant to the Understanding why seemingly simple design changes can have an impact. disproportionate to the timeframe and total cost of the project, especially when identified late or when not adequately communicated to the front lines of work impacted.

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Design changes: concept, nature and classification

Project alteration, for the purposes of this work, is understood as any modification.
introduced into the originally contracted project — whether in the basic design or in the design
executive — which involves changes to technical specifications, quantities, or methods.
constructive, executive sequence or physical configuration of the work, regardless of the
modification resulting from error, omission, field interference, scope change, or decision.
from the client. The project alteration is thus distinguished from a simple update of
Documents (drawing review without physical or contractual impact) and error correction.
Typing or drawing materials that do not affect the work to be performed.
Construction management literature classifies project changes according to different
criteria, especially their origin, nature, and effects on the performance of the undertaking.
(Sun; Meng, 2009; Hwang; Low, 2012). Regarding their origin, they can be classified as:
changes originating in the project (errors, omissions, incompatibilities between disciplines,
Insufficient detail in the basic project; changes originating in the field (interferences)
unmapped physical features, geotechnical conditions different from those predicted, interference with networks
existing); and changes resulting from a decision by the client (change of scope, of standard).
finishing, production capacity, layout, meeting subsequent requirements
(from licensing or regulatory bodies).

Regarding the nature of the impact, it is usual to distinguish between changes that do not modify the value or the
contractual term (adjustments to details without impact on quantities or services)
of those that effectively impact cost, time, or both, requiring, in the latter case...
In this case, specific contractual treatment through an addendum, service order or
equivalent instrument. As for criticality, changes can be classified as
Blocking factors — when they prevent the continuation of a work front until its definition —
or non-blocking, when they allow the execution to continue with subsequent adjustment.
This classification is not merely academic: it guides the definition of response times.
required of each party, the prioritization of technical analyses and the mitigation strategy of
impacts. Blocking changes, for example, require an accelerated approval flow, under
penalty of causing a work stoppage and, consequently, a direct impact on the
Critical path of the schedule. Non-blocking changes, in turn, although not
Interrupting the process requires strict control to prevent it from accumulating unnecessarily.

This record generates a reconciliation liability between what was executed and what was formally approved.

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Project Change Notification (PCN)

The Project Change Notification (NAP) is the formal instrument through which
an identified design change — whether in the field or in the technical office — is
registered, described, dated and forwarded for analysis and deliberation by the parties involved in
This is, in essence, a control document that precedes and...
This provides the basis for any potential contractual amendments, whose purpose is to ensure that no changes are made.
relevant aspects are incorporated into the execution without affecting their technical, time, and cost impacts.
have been previously evaluated and formally registered.

In general, a well-structured NAP includes, at a minimum: (i)
(i) identification of the work, the engineering discipline and the service affected; (ii) technical description of
change, with reference to the originally contracted project documents (revision of
(i) drawing, descriptive report, technical specification); (ii) motivation and origin of the change
(design error, field interference, contractor request, regulatory requirement)
(iv) preliminary impact assessment in terms of time, cost and quantities of
service; (v) supporting documentation (sketch, photograph, RDO, calculation report); and (vi)
field intended for the analysis and formal statement of the inspection or management of
contractor.

NAP thus fulfills three simultaneous functions: traceability, by linking,
in a unambiguous way, each change made in the field to a formal and dated record; function of
communication, by formalizing the flow of information between designer, contractor, and supervisor; and
Its function is to provide contractual support, as it constitutes the documentary basis upon which any eventual agreements will be based.
requests for extensions of time, additional services, or economic-financial rebalancing
of the contract. The absence of a structured process for issuing and controlling NAPs tends to
to produce a scenario in which changes are absorbed informally by field teams.
— through verbal instructions, non-centralized notes in RDO, or simple adjustments.
of design — without its effects being properly quantified, which compromises
both the planning and the subsequent measurement. It is
important to highlight that the NAP (Non-Application Plan) should not be confused with a contractual addendum, nor with...
replaces. The NAP is the instrument for identifying, describing, and preliminarily evaluating the
amendment; the contractual addendum (or equivalent instrument, such as a work order with implications)
(contractual) is the formal legal instrument that alters the originally agreed-upon conditions —
Timeframe, value, scope — based on the consolidation of one or more duly approved NAPs.

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Efficient management of large-scale projects therefore presupposes a consistent flow between the issuance of the NAP, its technical analysis and approval, and its eventual contractual formalization, of so that there is no disconnect between what is done in the field and what is recognized. contractually.

Field documentation and traceability

Traceability — understood as the ability to reconstruct the chain at any time. of the technical and contractual decisions that formed the basis for the execution of a given service — It depends directly on the quality and consistency of the field documentation produced. throughout the work. Among the most relevant field documentation tools for management Among the changes, the following stand out: the Daily Work Report (RDO), the photographic record and, when Applicable, video, preliminary as-built sketches and drawings, measurement reports, minutes technical and construction meeting reports, and non-conformity reports.

The RDO plays a central role in this set, insofar as it constitutes the record. chronological and contemporary of the relevant facts that occurred in the field — conditions climate, workforce size, equipment mobilized, activities performed, relevant occurrences and, above all, any inspection orders that imply Changes to the design or execution method. Case law from courts of accounts and practice.

Construction audit professionals have repeatedly highlighted the importance of the Daily Work Report (RDO) as an element of proof of the actual occurrence and timeliness of facts that support requests for extensions of time and cost, which is why its correct and consistent preparation is a prerequisite for the defense. technique for any design change.

Photographic records and georeferenced field documentation, in turn, fulfill supplementary evidentiary function to the RDO, allowing for the objective demonstration of the physical conditions encountered in the field (for example, an unmapped interference in project), the stage of execution of a given service on a given date, and the actual Performance of additional services that may be controversial. Absence of binding agreement.

systematic relationship between the photographic record, the corresponding NAP (Natural Assessment Point) and the measurement report of The time period is one of the most recurring causes of weakening contractual claims, since This makes it difficult to unequivocally demonstrate the causal link between the project alteration and the... service effectively measured.

Document traceability therefore presupposes a system — whether manual or computerized —

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capable of consistently linking each project change (NAP) to field records.
that evidence it (RDO, photographs, sketches), to the quantities executed (bulletin of
(measurement) and to any contractual instrument that formalizes it (addendum, work order). In
Without this integration, the organization tends to accumulate fragmented and disorganized documentation.
This difficult correlation compromises both contemporary managerial analysis and execution.
as for the subsequent historical reconstruction of the project in audits and expert analyses.
Dispute resolution techniques or processes.

Additional services and contract addendums

Additional service, or extra-contractual service, is defined as that which arises from an alteration.
The project was not included in the originally contracted scope, either because it was not listed.
from the reference budget spreadsheet, either because, although related to an existing item,
It exceeds the quantities or technical specifications originally agreed upon. A
proper characterization of a service as additional — as opposed to a service already included
understood within the original scope, even if executed by a different method — it is a critical step.
of the change management process, insofar as it determines whether or not there is a need for
specific contractual formalization.
In unit price contract arrangements, the incorporation of additional services
The contract is typically amended through an addendum that introduces new items to the spreadsheet.
budgetary, through the composition of a unit price compatible with the parameters
contractual and, where applicable, with market benchmarks or official cost tables (such as the National
System for Research on Costs and Indices of Civil Construction — SINAPI,
within the scope of Brazilian federal public contracts). Already in price-based contracting regimes.
Whether it's a global or EPC analysis, the analysis of additional services tends to be more complex, as it involves...
discussion on whether the change is effectively classified as a change of scope (outside of price).
closed) or as a risk already contractually allocated to the contractor.
Brazilian legislation on administrative contracts — historically Law No. 8.666/1993 and,
Currently, Law No. 14.133/2021 (Law on Bidding and Administrative Contracts) — regulates
percentage limits for additions and subtractions of services in public contracts, as well as
the formal requirements for the execution of addenda, reinforcing the need for
A solid technical justification is required for any change that implies an increase in value or timeframe.
contractual. Although in private contracts this specific legal discipline does not apply.

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directly, it is a consolidated market practice that the contractual instruments themselves
Large private companies replicate similar mechanisms of limitation and requirement of
Technical justification for scope changes, with a view to project governance.
The economic and financial rebalancing of the contract, in turn, constitutes the mechanism by which...
which re-establishes the original relationship between burdens and benefits agreed upon by the parties.
when supervening events not attributable to the contractor substantially alter the
Execution conditions foreseen in the original proposal. Project changes that imply
addition of services, alteration of construction method or execution sequence, or
Work stoppages can justify claims for rebalancing, provided that
duly demonstrating the causal link, the contemporaneity of the registration and the
objective quantification of impacts — elements that, once again, depend directly
of the quality of field documentation and the traceability of NAPs issued throughout the
execution.

Contractual measurement and control mechanisms

Contractual measurement is the periodic process—usually monthly in large-scale projects.
— verification of services actually performed, based on pre-established criteria.
defined in the contract (budget spreadsheet, measurement report, technical specifications),
intended to subsidize the corresponding payment to the contractor. The measurement is therefore not a
mere accounting procedure: it constitutes the main point of convergence between what was
planned (physical-financial schedule), what was contracted (budget spreadsheet) and what
It was effectively implemented in the field, including any design changes.
When a project change is not previously formalized through a NAP (New Approval Process) and, if
applicable, as a contractual addendum, the team responsible for the measurement faces a dilemma.
recurring: measure the service actually performed in the field, even if it differs from the item.
contractually stipulated as originally planned, at the risk of subsequent rejection due to lack of legal basis.
contractual; or strictly measure what is stipulated in the original spreadsheet, even if this does not reflect the
service actually performed, generating financial liabilities for the contractor and, eventually,
contractual dispute. This dilemma highlights why the timeliness of the NAP — that is, its
Issuance and analysis prior to, or at least contemporaneous with, the execution of the service—is a condition
essential for measurement consistency.
From a cost control perspective, periodic measurement feeds into the S-curve of physical progress.

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Financial and performance indicators of the project, among which the Schedule Performance Index (SPI) and the Cost Performance Index (CPI) stand out in the Earned Value Management (EVM) literature.

(Project Management Institute, 2021). Untracked project changes tend to distort
These indicators, since they introduce, in the basis of comparison between planned value, value
aggregate and actual cost, quantities and services that do not exactly correspond to the line of
original base — a phenomenon that the literature calls scope creep when it results from
Incremental scope expansions that are not formalized.
Contractual control, finally, encompasses the set of administrative and technical routines.
designed to ensure compliance between the execution of the work and the agreed conditions,
including monitoring the contractual balance (remaining values and quantities per
(item), monitoring the legal and contractual limits for addenda, managing liabilities of
NAPs pending approval or formalization, and the periodic consolidation of reports.
Managerial guidelines that support the decision-making of both the contracting party and the contractor. Effectiveness
This control is directly contingent upon the existence of a structured management flow.
Changes, a topic that will be revisited in section 6 of this article.

METHODOLOGICAL PROCEDURES

This article adopts a qualitative approach, with exploratory-descriptive objectives and a design.
bibliographic and documentary. According to Gil's classification (2022), bibliographic research
It allows you to organize and discuss previously published contributions on a given issue, while
Documentary research makes it possible to incorporate standards, legislation, technical guides, and other...
institutional documents relevant to the object of study. The choice of this approach stems from
with the objective of systematizing knowledge about managing project changes in construction projects.
large scale and, based on this synthesis, propose a technical workflow for practical application, without
claim of statistical generalization.
The literature review was conducted in a narrative manner, not as a systematic review.
The theoretical material was selected based on its thematic relevance and ability to substantiate the arguments.
Main areas of research: change management in construction projects; planning
and control; cost measurement and control; productivity and cumulative impacts; traceability
documentary; and contract management. Consolidated technical books and articles were considered.
National and international scientific references, project management guidelines, and documents.

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normative and institutional. In the document analysis, special consideration was given to the
Brazilian legislation applicable to contracts for engineering works and services and guidelines.
techniques related to project management and control. This methodological option
It seeks to ensure coherence between the sources analyzed and the research problem, without attributing to...
Exhaustive bibliographic survey.

The analytical procedure was developed in four stages. In the first stage, the following were identified
and the central concepts were systematized — project change, NAP, field documentation,
Traceability, additional services, contractual measurement, productivity, and cost control. In
Secondly, these concepts were related to explain the mechanisms by which the
Changes have repercussions on planning, scheduling, measurement, and costs. In the third
In this stage, the conceptual synthesis was used to structure the proposed management flow.
Changes and their control indicators, presented in section 6. In the fourth stage, the flow was
applied to a hypothetical and didactic situation, presented in section 7, with the purpose of
to demonstrate its operationalization and the articulation between field records, NAP, technical analysis,
Contractual regularization and measurement. The illustrative situation does not constitute a case study nor
Empirical validation of the model.

Due to a methodological limitation, the study does not use primary empirical data from
specific projects do not even perform statistical testing of the proposed flow. The conclusions
They should therefore be interpreted as the results of a theoretical-conceptual analysis and
documentary evidence, supported by selected literature, and not as evidence of quantitative validation.
of the model in a population of works. This delimitation stems from both access restrictions
both contractual and operational data of large projects and the purpose of
work, focused on systematizing the problem and formulating a technical reference.
Applicable. Future studies could test the flow and indicators proposed in case studies.
real data and compare their performance under different contractual arrangements.

IMPACTS OF PROJECT CHANGES ON PLANNING

Effects on the physical schedule

The most immediate impact of a project change on planning is manifested in
Physical schedule of the project. When the change affects an activity located along the path.
critical — that is, in the sequence of activities whose duration determines the total deadline of

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undertaking — any delay in its definition, approval or execution tends to be
to be fully reflected in the project's final deadline, unless offset by acceleration actions (fast-tracking or crashing) in subsequent activities. However, when the change affects activity with Available slack, the impact on the total timeframe can be absorbed, provided that the slack is not consumed by concurrent changes on other fronts.

Project changes identified late — that is, communicated to the execution team.
after the start, or even after the completion, of the impacted activity — can generate rework, demobilization and remobilization of teams and equipment, disposal of previously applied material and The need for reordering the executive sequence. Studies on change management in Construction companies associate the occurrence and accumulation of changes with negative effects on deadlines. cost, quality and productivity, especially when the change process is poorly structured. (Ibbs; Nguyen; Lee, 2007; Hwang; Low, 2012). In addition to directly impacting time consumption, rework This can affect subsequent productivity by disrupting the continuity of work fronts and by The need to replan activities.

Effects on resource allocation

Changes to the project also have repercussions on the allocation of human and material resources. and previously planned equipment. The introduction of an additional service, or the Modifying the construction method of a previously planned service often requires a profile of labor force different from that originally mobilized, equipment not foreseen in the original planning, or inputs with a lead time incompatible with the current schedule. When the change is identified and formalized in advance. sufficient — which presupposes an efficient flow of NAP issuance and analysis. —, It is possible To replan the allocation of resources in an organized manner, minimizing idle time and mobilization. emergency.

Conversely, when the change is identified only at the time of execution — scenario recurring in the absence of a structured change management process, the response of Construction teams tend to operate under deadline pressure, with the urgent mobilization of resources. contracting suppliers under less favorable commercial conditions and, frequently, sacrificing productivity in other areas of work to enable service to alteration. This reactive response pattern is one of the most characteristic manifestations of Lack of structured management of changes in large-scale projects.

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Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VII, v.1 2026 | Submission: 08/25/2026 | Accepted: 08/28/2026 | Publication: 08/31/2026

Ripple effect and productivity

International literature on construction management refers to this as the ripple effect, or cascading effect. the phenomenon by which a design change, even a specific one, propagates impacts on activities and subjects not directly related to the original purpose of the change, by means of the interdependence between work fronts. Ibbs, Nguyen and Lee (2007) discuss how cumulative changes over the course of execution — even when individually small — produce a productivity impact that is disproportionate to the volume of additional work that They represent a phenomenon attributed to factors such as loss of logical sequence of execution. increased physical interference between disciplines, increased workforce turnover and The decline in team morale due to recurring rework.

This cumulative effect is particularly relevant for the technical defense of related claims. the loss of productivity resulting from multiple design changes, a scenario in which the Demonstrating the impact cannot rely on a single change considered in isolation. but it depends on reconstructing the set of changes that occurred over a given period. period and its correlation with the actually observed drop in productivity — analysis which, once again, presupposes consistent document traceability between NAPs, RDOs and field productivity notes.

IMPACTS ON COST MEASUREMENT AND CONTROL

Discrepancies between what was planned, what was contracted, and what was measured.

The failure to formally submit project changes in a timely manner is one of the main causes of... divergence between three benchmarks that, in a mature contract management system, should remain consistent with each other: the planned quantity (foreseen in the physical-financial schedule and in the budget proposal), the contracted quantity (as stated in the current budget spreadsheet, (including any potential additives) and the quantity measured (actually determined in the field). (for payment purposes). When a change is made in the field without prior NAP and without With the corresponding contractual adjustment, the measurement team begins to deal with a quantity. executed that does not find an exact match in either of the first two references, forcing her to resort to stopgap solutions — such as forced classification as an item similar contractual arrangement, or measurement subject to reservation, pending subsequent regularization.

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These palliative solutions, while understandable from an operational standpoint, tend to to compromise the accuracy of management reports on physical and financial progress, since The reported percentage of completion no longer accurately reflects the actual scope. contracted. In scenarios of accumulated, unregulated changes — a situation relatively common in large-scale projects with a compressed schedule, the disconnect between measurement and contracting can reach a magnitude sufficient to compromise the very The reliability of the S-curve as a management control tool.

Direct and indirect costs resulting from changes

The costs associated with a design change are not limited to the direct cost of the service. Additional or modified — materials, labor, and equipment directly used in carrying out the alteration. It is also necessary to consider the indirect costs of the alteration.
resulting costs, among which the following stand out: rework costs, when the change implies demolition, removal or replacement of work already completed; demobilization costs and remobilization of teams and equipment; inventory costs and obsolescence of materials. acquired according to specifications prior to the change; financial costs associated with any eventual extension of the contractual term (maintenance of the construction site, technical team and structures) indirect costs for an additional period); and productivity loss costs, discussed in section 4.3, resulting from the cascading effect of cumulative changes.
Accurately determining these indirect costs is generally more challenging than determining the... Direct costs, as it depends on quantification methodology and a documentary basis capable of... distinguish the effects attributable to the change from those resulting from other factors of undertaking. Among the methods used in productivity loss claims.
The measured mile stands out, based on the comparison between periods or working conditions. impacted and not impacted, provided that a sufficiently reliable database exists and Comparable (Gulezian; Samelian, 2003; Trauner; Kay; Furniss, 2022). More recent studies They also emphasize the importance of contemporary and organized data recording. productivity for quantifying the impacts and costs associated with claims (Seo; Kim; Kang, 2022).

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Economic and financial rebalancing and contractual control

From a contractual perspective, project changes that imply an increase in cost, time, or...
both can form the basis for claims seeking economic and financial rebalancing of the contract, whose
origin generally depends on the cumulative demonstration of three elements: (i) the effective
(i) the occurrence of the change, and its origin in a fact not attributable to the contractor; (ii) the causal link of
causality between the change and the claimed cost or time impact; and (iii) quantification
The objective of this impact, based on recognized technical criteria and documentation of
Consistent support.

The robustness of these three elements is directly conditioned by the quality of the process of
Change management as described in section 2: NAP provides a formal, dated record of the change.
and of its origin; field documentation (daily reports, photographs, sketches) provides the evidence.
of contemporaneity and causal link; and traceability between NAP, documentation
Field data and measurement reports provide the basis for the objective quantification of the impact.

In this sense, it can be stated that the quality of change management in a project is a factor.
a determining factor — though not the only one — in the contractor's ability to gain recognition.
timely and complete handling of legitimate rebalancing claims, as well as the capacity of the
The contracting party must exercise effective control over what is actually being paid for as a modification.
scope.

From the perspective of broader contractual control, the existence of a significant liability of
Pending NAPs (Not Approved Procedures) awaiting analysis or formalization constitute, in themselves, a risk indicator for the...
undertaking, insofar as it signals a potential future disconnect between cost
incurred and contractually recognized cost, with repercussions on the cash flow of
contracted and regarding the contractor's budgetary predictability. The management of this liability — its
Identification, prioritization, and timely resolution—therefore, constitute a central component of
Cost control in large-scale construction projects, a topic revisited in the proposal presented in the section.
6.

PROPOSED CHANGE MANAGEMENT FLOW

Based on the systematization presented in the previous sections, this section proposes a workflow.
A structured project change management system, applicable to large-scale projects, organized
around five sequential and articulated steps: identification, formalization (NAP), analysis

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Technical and contractual aspects, approval and regularization, and monitoring through indicators. The adoption of Integrated systems for recording, evaluating, and monitoring changes find support in Literature on change management is under construction, which emphasizes the need to articulate decisions, information and impacts throughout the process (Motawa et al., 2007). The flow here The proposed approach does not intend to exhaust the particularities of each organization or undertaking, but to offer a conceptual framework adaptable to different sizes and contractual arrangements.

Proposed workflow steps

In the first stage — identification — the project change is perceived in the field (by inspection, by the execution team or the project team) or in a technical office (by incompatibility between subjects, for example), which should be immediately recorded in the Daily police report, with a summary description of the incident, even if the complete formalization is done through... if NAP occurs at a later time. This immediate registration in RDO is what ensures the The contemporary nature of the evidence is a central element for the strength of any potential future claim.

In the second stage — formalization — the identified change is consolidated into a NAP (New Administrative Procedure). containing the elements discussed in section 2.3: identification of the discipline and the service affected, Technical description of the change, motivation and origin, preliminary impact assessment within a given timeframe. and cost, and supporting documentation (sketch, photograph, reference to the corresponding RDO).

It is recommended that the issuance of the NAP (Nota de Apoio Própria - Permit to Approval) observe the maximum deadline defined in internal procedures. — for example, a few working days from the identification of the change — in order to preserve The timeliness of information and avoiding the accumulation of informal changes.

In the third stage — technical and contractual analysis — the NAP is submitted to review by the inspection authority. and the relevant technical areas of the contracting party (or of the project management, when applicable). delegate), who assess the technical relevance of the change, its classification as a service already in place. whether included in the original scope or as an additional service, and the reasonableness of the impacts. Preliminary timelines and cost estimates have been provided. This stage should be conducted based on criteria. Objective and documented technical aspects, avoiding automatic approval—which weakens the process. Contractual control — regarding excessive delays, which increases the risk of accumulating [problems/issues]. The outstanding NAP liability is discussed in section 5.3.

In the fourth stage — approval and regularization — the approved NAPs are consolidated. periodically, in a contractual addendum (when involving an increase in value or term). or of relevant scope) or incorporated directly into the current measurement spreadsheet (when

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Included within the limits and nature of the current contract, without the need for an addendum. (formal). Periodic consolidation — for example, monthly, in sync with the cycle of Measurement — prevents both excessive fragmentation of additives and the accumulation of alterations. not regularized for long periods.

In the fifth stage — monitoring by indicators — the organization tracks, in a way systematic, a set of control indicators related to the management process of changes, discussed in section 6.3, that allow for the timely identification of deviations relevant factors — such as the growth of outstanding NAP liabilities, the increase in average maturity of analysis, or the concentration of changes in a particular discipline or area of work, signaling a possible need for project revision or reinforcement of technical coordination.

Integrated document traceability

The structuring element of the proposed workflow is integrated document traceability, that is, the Systematic linking between the different records produced throughout the process: the RDO. which highlights the contemporary nature of the change identification; the NAP that formalizes its description, origin and preliminary impact; supporting documentation (photographs, sketches, calculation records) that demonstrate its technical materiality; the technical report from the inspection; the addendum or spreadsheet adjustment that formalizes it contractually; and the measurement report. which reflects its incorporation into the payment. Table 1 summarizes this correlation.

Instrument	**Stage of the process Main function**	
RDO	Immediate identification	Record the occurrence contemporaneously. field
NAP	Formalization	Describe, motivate and measure preliminary change
Documentation of support	Formalization / Analysis	To technically demonstrate the alteration (photos, sketches, calculation notes)
Technical opinion	Analysis	Assess technical relevance and appropriateness. contractual
Addendum / Adjustment of spreadsheet	Approval and regularization	To legally formalize the change of scope, timeframe, or value

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Measurement report	Monitoring	Reflect the change in revenue and in physical-financial progress

Table 1 — Correlation between traceability tools in the change management workflow.

Source: compiled by the author.

The link between these instruments can be operationalized through a single code.
tracking, assigned to each NAP and replicated in all related documents
(reference in the original RDO, in the measurement bulletin in which the service is incorporated and in
(corresponding additive term), a practice that, even in environments with a low degree of
Computerization allows for the complete reconstruction of the history of any change from...
any of the documents in the chain. In more mature environments, this traceability can
be supported by computerized construction management systems (BIM 4D/5D integrated with systems)
document management systems), which partially automate this linking and reduce
the risk of inconsistency arising from manual control.

Key performance indicators (KPIs) for change management

The operationalization of the proposed workflow presupposes the periodic monitoring of indicators.
Key performance indicators (KPIs) that allow the client and contractor to monitor, in a way
The objective is to ensure the health of the change management process. Table 2 summarizes the main points.
Suggested indicators, their calculation method, and their managerial purpose.

Indicator	**Calculus (summary)**	**Purpose**
Average review time of NAP	Average (date of opinion ÿ date of NAP issuance)	Monitor the timeliness of technical analysis
Liabilities of NAPs pending	Number of NAPs issued - Number of NAPs formalized/approved	Signaling a risk of detachment. between executed and recognized
Percentage of value additive	Total added value / Value original contract	Keep track of legal limits and contractual amendments
Index of changes by discipline	Number of NAPs per subject / Total NAPs	Identify subjects with the highest incidence of change

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Productivity deviation during periods of change	Productivity comparison between periods with and without NAPs productivity relevant	Estimate the impact of loss of (ripple effect)
Adhesion RDO–NAP–Measurement	Number of NAPs with complete registration. in the chain / Total NAPs	Measure the integrity of document traceability

Table 2 — Proposed control indicators for project change management. Source: Prepared by the author.

The systematic monitoring of these indicators, with a frequency compatible with the cycle. Measuring the project allows not only reactive control of the process — identifying deviations that have already occurred—but also using them as a management tool. preventive, by highlighting, for example, the recurring concentration of changes in a particular area. design discipline, which may indicate the need for early design review. executive of that specific discipline, with the potential to mitigate further changes before impact the execution.

DISCUSSION: ILLUSTRATIVE SITUATION APPLIED

With the purpose of illustrating, in a practical way, the operationalization of the flow proposed in the section 6, this section presents a hypothetical and didactic situation — without correspondence to identifiable real undertaking —, built from recurring patterns discussed in Literature on the management of large-scale construction projects. The situation involves a hypothetical industrial construction project. in which, during the execution of the foundations of a large piece of equipment, the inspection Identifies, in the field, an interference not mapped in the project: an underground pipeline of utilities, belonging to an existing installation, located at the exact position of one of the footings. as foreseen in the detailed design.

In the illustrated situation, the inspection team records the occurrence in the daily police report, with a sketch. Location and photographic record of the interference, immediately after its identification — thus preserving the contemporary nature of the evidence. The NAP is issued on the following business day. corresponding, describing the interference, its origin (insufficient cadastral survey). (in the basic design phase) and the estimated preliminary impact: need for repositioning from the foundation, with additional excavation and concrete work, and partial shutdown of the work front.

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Year VII, v.1 2026 | Submission: 08/25/2026 | Accepted: 08/28/2026 | Publication: 08/31/2026

foundations for an estimated period of five working days until the design solution is defined.

The NAP (Notice of Appropriate Planning) is analyzed by the structural design team and the inspection team within a reasonable timeframe.

with the internal procedure of the work, resulting in a technical opinion that approves the

Repositioning of the footing according to the alternative presented by the designer, with quantification.

Regarding the addition of services (excavation, concrete, reinforcement) and confirmation of the timeline impact.

Estimated on the foundation front. Due to the interference affecting activity located there.

As the critical path of the foundation schedule approaches, the planning team assesses,

Additionally, the possibility of bringing forward other foundation fronts that are not impacted,

in order to partially mitigate the effect on the total project timeframe — application

The practice of the fast-tracking concept discussed in section 4.1.

At the end of the month, the additional repositioning service is incorporated into the measurement report.

of the period, with explicit reference to the corresponding NAP tracking code, and to

The change is consolidated, along with any others that may have occurred during the same period.

in a monthly addendum to the scope regularization agreement. The RDO-NAP- adherence indicator

The measurement, discussed in section 6.3, remains fully satisfied for this occurrence, in

to the extent that the entire documentary chain — RDO, NAP, technical opinion, measurement and addendum —

It is consistently linked through the unique tracking code.

The situation illustrated allows us to highlight, in a concrete way, the elements discussed throughout.

From the article: the importance of immediate identification and registration in RDO for the preservation of

contemporary relevance of the evidence; the role of NAP as an instrument for formalization and

Preliminary impact assessment; the relevance of timely technical analysis for mitigation.

of impacts on the critical path; and the importance of integrated document traceability.

for consistency between the service performed, the service measured, and the service contractually agreed upon.

recognized. In contrast, it is possible to infer, from the literature discussed in sections 4 and

5, that the absence of any of these steps — for example, the non-issuance of NAP, or the

Excessive delay in its analysis would tend to compromise the technical defense of the service.

additionally, this generates a discrepancy between what was executed and what was measured, and amplifies, rather than mitigates, the

impact of the interference on the total timeframe of

undertaking.

FINAL CONSIDERATIONS

This article aimed to analyze, from the technical perspective of cost engineering and...

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Project management, such as project changes that occur during construction.
Large-scale projects influence the timeline, cost, and contractual measurement, with a specific focus on...
Project Change Notification (PCN) instruments, in field documentation, in
Traceability, in additional services and in contractual control. Based on a literature review.
of planning and control of works, project management and contract law
In engineering, it was possible to systematize the main concepts involved and discuss the...
mechanisms by which design changes affect planning and...
measurement and cost control.
The results of the analysis indicate that unmanaged project changes
tend to produce effects that propagate silently through the planning chain and
control: compromises the accuracy of the physical schedule, through rework and other negative effects.
cascading across related activities and disciplines; they generate discrepancies between the quantitative
planned, contracted, and measured, weakening the reliability of management reports.
physical and financial progress; and compromise the robustness of any potential claims for rebalancing.
economic and financial, by not ensuring contemporaneity, causality and the
objective quantification required for its technical and legal validity.
As a central contribution, this article proposed a structured change management workflow.
organized in five stages — identification, formalization through NAP, technical analysis and
contractual, approval and regularization, and monitoring by indicators. —, linked to a
set of integrated document traceability tools (RDO, NAP, documentation)
(support, technical opinion, addendum and measurement report) and control indicators
Key Performance Indicators (KPIs) specifically focused on the change management process. The illustrative situation
The information presented in section 7 demonstrated, in a practical way, how consistent operationalization...
This flow is able to preserve traceability and mitigate deadline impacts through...
timely response, and ensuring consistency between the service performed, the service measured, and the
contractually recognized.

From a practical standpoint, the results of this work suggest that investments in processes
and, where applicable, in computerized change management and documentation systems.
field—even though they represent an additional management cost in the short term—tend to be
This translates into reduced risk of contractual disputes and greater budgetary predictability.
for the client and in greater security for the contractor in the technical defense of legitimate claims,
Therefore, it constitutes an investment with the potential for significant returns in large-scale projects.
in which the absolute value of any deviations in schedule and cost tends to be significant.

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Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
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Year VII, v.1 2026 | Submission: 08/25/2026 | Accepted: 08/28/2026 | Publication: 08/31/2026

As a future research agenda, it is suggested that empirical case studies be conducted, with Access to real data from large-scale projects — provided due diligence is preserved. contractual confidentiality — capable of quantifying, in a statistically robust way, the correlation between the maturity of change management processes and indicators of Schedule and cost performance (such as the SPI and CPI ratios from the earned value methodology). It is also suggested that the potential of information modeling technologies be investigated. Building Information Modeling (BIM) and computerized document management systems in the automation of Document traceability is discussed in this article, as well as comparative studies between different contractual arrangements (unit price contract, lump sum contract and EPC) regarding More appropriate mechanisms for managing project changes.

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Year VII, v.1 2026 | Submission: 08/25/2026 | Accepted: 08/28/2026 | Publication: 08/31/2026

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