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Exploring Pre-Construction Activities in Infrastructure Projects That Can Benefit from Contractor Involvement

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Abstract: The pre-construction phase of public infrastructure projects is characterized by significant uncertainty as crucial decisions are made with limited information. This early stage of project development is influenced by a multitude of factors and input from various stakeholders. While early contractor involvement (ECI) offers potential benefits for both clients and projects, the timing and selection of tasks for involving the contractor are critical to achieving these benefits. This study seeks to identify key pre-construction activities in public infrastructure projects and pinpoint the activities that stand to gain the most from ECI. The research methodology involved conducting semi-structured interviews, organizing seven workshops, and conducting the literature and document studies. Through these efforts, the study identified a total of 20 pre-construction activities, among which 5 activities emerged as the most favorable candidates for ECI, while 5 others were deemed less suitable. The findings underscore a consensus that involving contractor expertise during the Brief Development sub-phase holds significant promise. Notably, activities associated with planning, environmental considerations, and technical aspects related to the scope clarification, were found to be highly amenable to ECI. Activities addressing uncertainty management received particular attention, with clients valuing contractors' practical experience in risk assessment and mitigation. Additionally, contractors' insights into planning, activity dependencies, and their contributions to health, safety, and environmental plans were highly regarded. However, activities, categorized under the more technical sub-phases of Concept Development and Detailed Engineering yielded mixed results, while those falling within the predominantly social and political domain and involving political processes and societal impact, were viewed as less suitable for early contractor involvement. These findings emphasize the need to adopt a systematic and consistent approach to pre-construction activities, highlighting that ECI should not be applied as a one-size-fits-all solution. The interview results somewhat contrast with the literature findings, which indicate that the early conceptual phase is most beneficial as the contractor impact is highest. To some extent, the client, contractor, and consultant still see their benefit and strategy before the good of the project.

Keywords: ECI; infrastructure projects; pre-construction; activities

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1. Introduction

Large infrastructure investments are a vital component of any public or private institution, but cost overruns, delays, and exaggerated benefits are the norm rather than the exception for roads, bridges, stadiums, concert halls, and new plants [1]. The early phases of project development and scoping are influenced by a wide range of issues and stakeholder inputs [2]. A stakeholder assessment performed by Gaur et al. [3] shows that the client, along with the contractor and project manager, forms the top three stakeholder groups under internal stakeholders in construction projects as they act as the key drivers of the project. Similarly, the customers, local community, and utility service providers form the three important stakeholders under the external category [3]. It is acknowledged that the contractors are both the main stakeholders and key drivers, so the question of when and how they should contribute arises as their involvement has an impact on both the project outcome and the other stakeholders. The time aspect of construction projects is an issue since the average length of the time from the start of planning to the start of operations for a large infrastructure project is commonly 10–15 years [1].

Early contractor involvement (ECI) refers to the engagement of the contractor at the early stage of project development, before construction commences, through a wide range of approaches [4]. Among other things, the early involvement of the contractor has proven to have a positive impact on the quality of the design in many respects, and the findings suggest that the earlier a contractor gets involved in the design, the more the quality of the design can increase [5,6]. Research shows that in ECI, the design process can benefit from the expertise and knowledge of the contractors in terms of buildability, construction methods, materials, and local practice [6–8]. Although some projects will benefit from contractor input as early as the project inception, others will benefit more during the feasibility or investigation phase, whereas some projects will only benefit during the design phase. In addition, there are some projects in which contractor involvement is of no significant value and may simply add cost and will not reduce delivery time [2]. This is because ECI does not necessarily add any value to less complex projects [9,10].

Although previous studies argue for how contractor involvement can make an impact, the timing is still highly uncertain. As presented, previous studies examine evidence both for and against contractor involvement, depending on the nature of the project, while referring to the early involvement itself as something that happens in the pre-construction phase. This timing is somewhat imprecise as the pre-construction phase is long, involves many stakeholders, and is both comprehensive and circumstantial in technical, financial, and legal aspects [8,10]. There is, therefore, a need to systematically break down the pre-construction phase and identify the major activities, making the scope of work more transparent. In addition, it will be more obvious which activities need additional attention due to their complexity and what impact certain activities have on succeeding work [9,11–13]. When considering contractor involvement, there is also uncertainty as to whether the client, the consultant, or the contractor should perform certain work in its entirety or partly [14,15]. The breakdown into activities contributes to mapping the nature of the work more precisely, hence showing the uniqueness of each construction project. This leads again to a more objective and knowledge-based approach to the ECI evaluation process [15].

Therefore, this study aims to identify the main activities performed during the pre-construction phase and find when it is most beneficial to involve the contractor. This study does not consider the indirect value created by involvement in previous activities (i.e., what impact the involvement in activity 1 has on activity 2) but evaluates different activities individually.

For the above purpose, this paper aims to answer the two following research questions:

RQ 1: What are the main pre-construction activities for public infrastructure projects?

RQ 2: Which of the main pre-construction activities can benefit the most from ECI?

This study is limited to Norwegian public infrastructure projects and the pre-construction phase. It is also limited to the client's perspective (as it is the client that regulates/controls the contractor's involvement), but the client's perspective is supplemented with the consultant's and contractor's point of view to balance it.

The beginning of this paper consists of an introduction chapter presenting the background, the research gap, and the research questions. Section two is the theoretical background, followed by the Method Section explaining the data collection and the analysis process. Section four presents the findings from the literature and document studies, interviews, and workshops, whereas Section five is the Discussion Section. The final section presents the conclusion, including the practical and theoretical contribution of this work.

2. Theoretical Background

2.1. Construction Project Lifecycle Models and the Pre-Construction Phase in Infrastructure Projects

A comparison study by Tadayon et al. [16] was performed where the most common project lifecycle models applied in the construction industry were reviewed. Project Management Institute (PMI) PMBOK®, Royal Institute of British Architects (RIBA) Plan of Work, Property Federation (BPF) Manual, British Airports Authority (BAA)—The Project Process, Ministry of Defense (MOD)—Working Document, Prince2, and Neste Steg/Next Step were compared to identify a lifecycle that reflects the construction process of infrastructure projects most adequately. Studies concluded that the Neste Steg framework is the most suitable model [16]. Bygg21 (a collaboration between the construction and property industry and state authorities in Norway) created the Neste Steg, which is a framework that describes the construction process over time, in eight steps from start to finish [16,17]. The framework was inspired by the RIBA Plan of Work [18]. The purpose was to develop a common norm for the phasing of construction projects and, thus, develop an efficient common reference and language for the industry. Neste Steg highlights four different perspectives: the owner's, the user's, the executive's, and the public's. Used correctly, Neste Steg could have the potential to map what needs to be done, when, and by whom [19]. This framework also elaborates on how one's delivery affects someone else's. The model itself, having its breakdown structure, yields an expectation of proactive participation and cooperation as it clearly emphasizes dependencies between the parties involved. Recently, Neste Steg has been further developed into a Norwegian standard, *NS3467:2022 Steps and deliveries in the building's lifecycle* [20]. Figure 1 shows the overview of the framework. In Neste Steg, the pre-construction phase is defined from step 1 to and including step 4 (in this paper the Neste Steg steps are referred to as sub-phases).

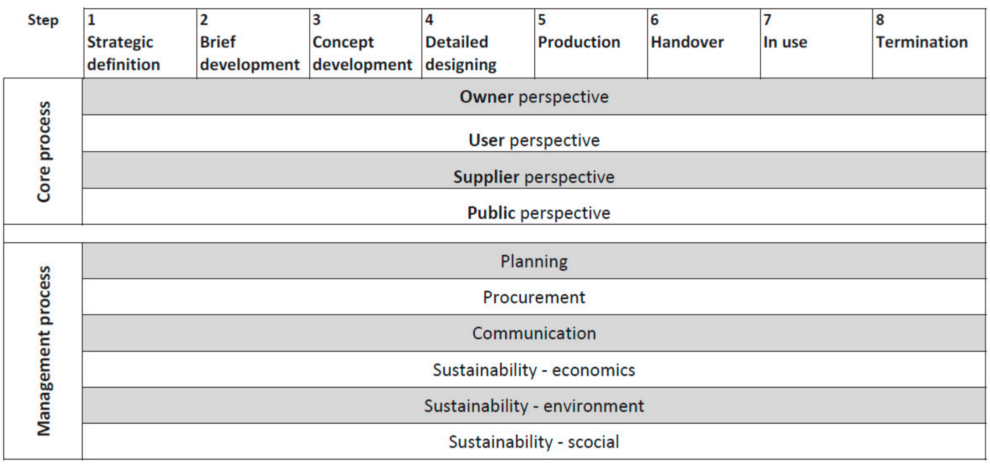

Figure 1. Neste Steg framework [18].

2.2. Activity-Based Approach to the Pre-Construction Phase—Infrastructure Projects

The pre-construction phase of a project is divided into different sub-phases, which consist of a set of activities that reflect the pre-construction process [16]. Neste Steg's framework identifies a set of activities belonging to the four perspectives. Between the steps, various decisions must be made, and these decisions determine whether we should move on, go back to the start, or perform additional work. These decisions are based on certain deliverables, which are an outcome of specific activities performed [19]. Although the Neste Steg framework identifies a set of activities, the list of activities can be assumed to be an inexhaustible list, depending on the criteria used for splitting the activities. According to the Federal Highway Administration (FHWA), it typically takes from 9 to 19 years to plan, gain approval for, and construct a new, major federally funded highway project that has significant environmental impacts. The time required varies with the size, complexity, and public interest in the project. It is estimated that as many as 200 major steps can be involved in developing a transportation project from the identification of project needs to the start of construction, depending on the project type and complexity [12]. These steps also require authorizations from various organizations or other stakeholders associated with the project and the duration of these approvals is often underestimated when the project is scheduled [12,21]. The activity-based approach in the industry was also initiated by the Organization for Economic Co-operation and Development (OECD), which trialed a new evidence-based tool, STEPS, to inform procurement decisions on major infrastructure projects and evaluate whether certain activities are 'make or buy'. The tool was applied to two major road projects in Norway belonging to NPRA and Nye Veier. The assessment is based on two economic theories—Transaction Cost Economics and Resource-Based Theory [15]. The tool consists of six steps where the project is broken down into activities and collected in packages that require different competencies and expertise. Activities are thereafter analyzed to determine their economic attributes, where the client performs the 'make or buy ' analysis, i.e., evaluates if the activity should be delivered in-house or bought on the market. It is worth mentioning that STEPS does not precisely qualify what competencies and capabilities an organization should have to engage in different delivery models. The authors recognize that the tool could benefit from more precise methods support material on determining the required competencies an organization should possess for engaging in various delivery models [15]. Defining activities properly has been an ongoing work in the industry for some time. Since 1994, the Construction Industry Institute (CII) has developed the Project Definition Rating Index (PDRI) tool to be used in the front-end planning (FEP) process [22]. The FEP planning, also defined as pre-project planning or design development, encompasses the project activities shown in Figure 2 [23]. PDRI-Infrastructure Projects (IR 268-2) identifies and precisely describes each critical element in a scope definition package, assuring that the breakdown into controllable activities is in line with the current maturity of the project. The review in 2i identifies and plans the remaining activities to achieve the level of detail necessary to complete the front-end planning in preparation for Phase Gate 3. The reviews are designed to evaluate the completeness of the scope definition at any point before the detailed design and construction.

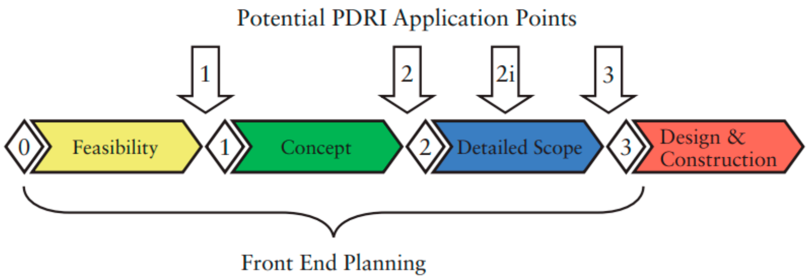

Figure 2. Project lifecycle diagram and potential application points at which the PDRI could be useful [23].

The idea is that the PDRI can benefit owners, designers, and constructors as owners can use it as an assessment tool whereas designers and constructors can use it as a method of identifying poorly defined project scope elements. Project size, complexity, and duration will help determine the optimum times when the PDRI tool should be used. The PDRI is divided into sections and categories and has identified an extensive list of activities relevant to infrastructure projects. IR 268-2 states also that research has shown that the PDRI can be effectively used to improve the predictability of project performance, but that PDRI alone will not ensure successful projects [23]. Studies by Safa et al. [24] on 70 industrial projects show that by applying the PDRI, there are clear benefits as it prompts the owner and the design team to perform an initial validation of their business and design assumptions compared with jurisdictional necessities and public expectations. Nevertheless, the use of the PDRI (Infrastructure) alone could not confirm the success of projects.

The pre-construction phase is the foundation of a project, ensuring timely construction within allocated resources [25]. The search for appropriate activity identification and dependency is, therefore, essential in proper project planning. As construction projects are notably time-consuming [1,12,26], there is a motivation to overlap the design phase activities to save time and identify the appropriate cost-saving strategy depending on the total rework and complexity generated [11,13]. The standard scheduling techniques, such as the critical path method, are not sufficient as during the overlapping optimization process, critical paths may change and new critical paths may emerge [13,27].

2.3. Classification of the Pre-Construction Activities in Infrastructure Projects

The National Cooperative Highway Research Program (NCHRP) identified several of the major activities performed in the pre-construction phase and classified these activities into four main types of pre-construction services: design-related, cost-related, schedule-related, and administrative-related [28].

A similar classification was accomplished by Al-Reshaid et al. [29], where it was concluded that the pre-construction phase can be monitored by the output reports, i.e., the pre-construction phase and belonging activities are divided into the four systems (scheduling, cost, financial and administration, and engineering systems), as shown in Figure 3.

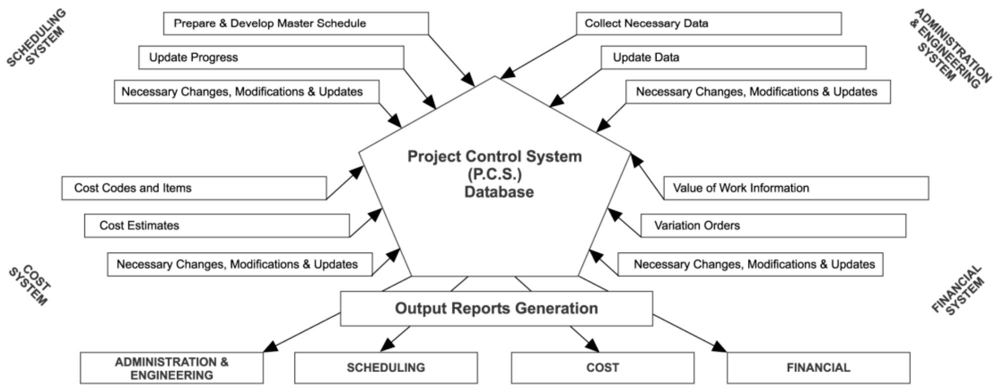

Figure 3. Project control system for construction projects [29].

2.4. ECI—Goals and Opportunities in the Pre-Construction Phase

On a higher level, it is seen that several of the UN's sustainable development goals are directly dependent on the construction industry [30]. All public road projects are subjected to various policy documents and must have defined societal goals, impact targets, and performance targets [31]. The Project Management Institute (PMI) Standards Committee defines project stakeholders as individuals and organizations who are active in the project. When compared with traditional construction projects, mega-construction projects emphasize more types of stakeholders, such as the public, suppliers, financial institutions, end users, and professional associations [32]. Similar is found by CII, where the PDRI Selection Matrix indicates that infrastructure projects have extensive interfaces with the public, the environment, and the jurisdiction [23]. Although the traditional philosophy of management in construction is mainly focused on proper planning and execution, the pressures of project performance can obscure the social, economic, and professional context. Strategic management in the context of the construction industry comprises seven areas—(1) Vision, Mission, and Goals, (2) Core Competencies, (3) Knowledge Resources, (4) Education, (5) Finance, (6) Markets, and (7) Competition—where (1) is the starting point for all organization endeavors as it establishes a vision and provides each member with a direction to follow in all business practices [33]. Findings by Ferme et al. [34] show that there is a direct relationship between the value of the project and the amount of input from stakeholders, including the social sustainability efficacy levels of construction projects during the pre-construction planning and design stages, and the research concludes that the project stakeholders' involvement' is the most significant main factor, followed closely by 'focus on project end users' [35].

Similar findings to those above are identified by Boge et al. [36], indicating that Norwegian respondents assume that technical contractors can bring in new knowledge and experience and, thus, contribute to both innovation and value creation, at least in the short-term perspective.

In the construction industry, the term value is broad as value creation can be understood according to three separate levels of analysis: strategic, tactical, and operational [37]. *This study does not cover how value creation is defined but does include both the process and product value as described by Thyssen et al. [38] at the levels described by Hjelmbrekke et al. [37] This paper uses the term 'intended value' throughout the article, referring to the unique value definition for a specific project, as defined by the project owner.*

The idea of involving the contractor as one of the prominent stakeholders can be referred to as ECI where ECI is defined as a form of organizational integration [39]. ECI is an approach to contracting that can complement either a traditional or novated design, build a delivery model, and be used to gain early advice and involvement from a contractor in the buildability and optimization of designs [40]. Although the tendency of having a formal contract is identified as a criterion for to use of ECI [8], as this paper intends to answer the question concerning which pre-construction activities can benefit the most from ECI, ECI is treated as a concept that facilitates contractor involvement and not a procurement method.

The research has acknowledged the significance of effective planning practices and integration of the designer and contractor in the early stages of the construction project lifecycle [41–43]. Findings show that when pre-construction planning was done properly, slippage of project schedules and overruns of the project costs could be mitigated to a great extent, if not eliminated [29]. According to Naoum [44], the rate of labor productivity on site can largely be affected by activities related to the pre-construction phase, identifying the main components to be ineffective project planning, delays caused by design errors, and variations, communication system adopted, design and buildability-related issues, including specifications and the procurement method adopted. These findings contribute to building upon the importance of integrating design and construction to achieve buildability and, as a result, increase productivity. This is presumed to be accomplished by increasing the awareness of the significant impact of allowing contractors to be involved at the pre-construction stage [44]. In the pre-construction phase, the conceptual sub-phase of any design project is identified as the most vibrant, dynamic, and creative stage of the overall design process. Still, it is least understood as the lack of understanding of the conceptual design process is in part because of the diverse range of disciplines and perspectives that result from collaborative work. The existing design procedures that are available to the interdisciplinary design team tend to be simple lists of deliverables rather than guidance documents providing design teams with an outline of what to do and by what method it should be achieved [45]. Sarbini et al. [46] identified the key design issues during the conceptual design review stage and the detailed design review stage. According to the results, the key design issues in the conceptual sub-phase involve the site condition, environmental influences, ground or groundwater condition, existing structure, demolition, services, proximity to major infrastructure facilities, traffic disruption, access to work, and site restrictions. The detailed sub-phase involves the mechanized construction systems, installation of prefabrication components, ease of the process, and layout optimization, among others [46].

On the other hand, excessive design reviews by the contractor were found to delay project progress. The general understanding was that the principle of ECI was welcomed by most project participants, where consultants, engineers, head contractors, and subcontractors all wanted to be involved in the project at approximately 30–40% documentation, if not earlier [34].

Still, the contractor involvement is not consensual—a study by van der Walt et al. (2019) shows that the client organizations argue that involving the contractor too early may prompt ownership of the project, which can result in unwanted disagreements later if the contractor in question is not engaged as the constructor. The contractor, client, and consultant agree that engaging the contractor early can be beneficial to the outcomes of a project, but that there is a difference between the optimal time for involvement for different parties. The contractors believe that involvement should occur in the concept design sub-phase, while the client's opinion varies from the project definition sub-phase to the detailed design sub-phase, and the consultant would like the involvement to occur at the latest phase [14]. Although the contractor and owner both feel the design phase can progress faster with ECI, the consulting parties do not think there will be any significant time savings during this period [2].

The biggest opportunities ECI can create for a project are the enhancement in constructability, improvement in working relationships, greater certainty in price and scope, and enabling innovation [9]. Through early contractor involvement, designers and contractors can collaborate to optimize methods as well as integrate innovation in the projects because ECI, as an approach, offers flexibility for both the owner and contractor [47]. At the same time, some studies identify challenges in implementing a successful ECI. For projects delivered under ECI, public clients have experienced the following: demonstrating value for money, unfamiliarity with the ECI process, the inadequacy of remuneration, lack of adequately trained resources, change in relationship protocol, cultural barriers, misuse of the relationship by the contractor, and imbalanced leadership [9]. This was also the conclusion reached by Botha and Scheepbouwer [48], who investigated 288 projects that were constructed with and without pre-construction services input, where it was shown that complex projects benefited most from the engagement of contractors in the pre-construction phase [49]. The use of ECI, whether informal and interactive or formal and documented, provided price certainty to client organizations through the provision of construction input during the design and the identification of construction risks [48].

This is why ECI as a project delivery system is not considered a 'one-size-fits-all' solution and needs to be adopted for a project carefully, through analysis of the project constraints and stakeholders' objectives [8,10]. For standard and less complex projects, there may be less value that can be added by using ECI as contractor involvement too early in the process increases bureaucracy and expenses due to the procurement process [10]. This can be supported by studies on critical success factors for large construction projects (based on the perspective of both consultant and contractor), which concluded that both parties believed competency and capability of the contractors to be most critical [50]. These findings indicate that ECI is situational and highly dependent on complexity where the contractor's expertise is crucial.

When considering the above and acknowledging that ECI does not necessarily add any value or that the timing is uncertain, there is a need to identify activities that cover the scope of the project so activities relevant to ECI can be evaluated more systematically.

3. Method

According to Creswell [51], the knowledge claims, the chosen strategy, and the method all contribute to a research design approach that can either be qualitative, quantitative, or mixed. Quantitative research is numerical in nature, whereas in the qualitative approach, the researcher seeks to establish the meaning of phenomena from the views of participants and study patterns of behavior. The mixed method approach combines the qualitative and the quantitative approaches with the purpose of gaining a more complete understanding of the research question, yielding an additional dimension than either one of the above approaches alone [52]. This paper has used a mixed approach to answer the research questions.

To build up and understand existing knowledge, a literature and a document study were performed. Thereafter, the first workshop was carried out to present and validate the findings. The takeaways from the first workshop were used to develop an interview guide and followed by 22 semi-structured interviews with industry professionals (17 interviews with the client side, 3 interviews with the consultant side, and 2 interviews with the contractor side). To complete the data collection, six workshops with industry and a group interview with the contractors were carried out.

As it is the clients that facilitate contractor involvement, the results are therefore from a client perspective, supplemented with the contractor and consultant view. The data collected ear for larger research. For this study, only a portion of the collected data is extracted and presented.

3.1. Literature and Document Study

The first step in the research process consisted of a literature and document study, which included the study of previous projects and project delivery models. The initial literature study, presented in the first layer, following the prescription of Blumberg et al. (2014), was undertaken to develop the theoretical background for this study and extract the initial list of activities from the available literature [53]. Search terms included but were not limited to keywords 'project delivery model', 'contractor', 'teams', 'pre-construction services', 'pre-construction phase', and 'activity'. The literature study was undertaken using the search engines Oria (Norwegian University library resource) and Google Scholar. Journal articles, conference papers, and government and industry documents covering different guidelines to manage the project included different project delivery models. This study used delivery models from six industry partners (NPRA, WSP, Nye Veier AS, Veidekke, Bane Nor, and Bodø Municipality) to compare and support the literature findings.

3.2. Interviews

After the literature and document studies, twenty-two semi-structured interviews were performed. The aim was to better understand the industry practices and triangulate the data collection method. The interviews were undertaken on Teams (due to COVID-19 restrictions) with industry professionals in Norway. The interviews were carried out between January and April 2021. Each interview took approximately two hours while recorded, and the main points were extracted and transcribed on a shared screen with the interviewees so they could comment and verify the findings. During the first sequence of interviews, the interviewees were asked to evaluate each of the identified activities with 'Yes/No' and whether the activity could benefit from ECI. If the respondent said 'Yes', they had to grade each activity on a Likert scale (1 to 5) based on the potential benefit that can be gained by engaging contractor competencies (1—minimal benefit, 5—maximum benefit). The respondents were then asked to elaborate on their responses and explain which party (contractor, client, consultant) had a better understanding of the specific scope of work and better competencies to perform the required work. To ensure that the set of activities identified covered the scope of work belonging to the pre-construction phase, the interviewees were also asked to confirm that all main work was covered in these activities.

Most interviewees had more than 10 years of experience in project environments while three worked 5 to 10 years as project managers. Participation in the interview series was voluntary and the responses were anonymous. In addition to the semi-structured interviews, a group interview was undertaken in 2023, with HENT, a Norwegian contractor company. The interview lasted for 1.5 h. Table 1 shows an overview of the interviewees, their role, and their organization.

Table 1. Participant organization and role.

Interviewee	Organization	Position
P1-P6	Bodø Municipality	Project director (1), Project manager (4), Procurement manager (1)
P7-P11	Bane NOR	Project manager (2), Project Director (1), Contract manager (1), Project Planning (1), Control manager (1)
P12-P16	Nye Veier (incl. 2 contractors)	Project Planning and control manager (1), Project manager (2), Portfolio controller (1), Project director (1)
P17-P19	WSP (consultant)	Project manager (2), Head of Planning (1)
P20-P22	NPRA	Project manager (2), Engineering manager (1)
Group (4)	HENT (contractor)	Head of Project Development (1), Project manager (3)

3.3. Workshops

Seven workshops, with an average duration of approximately five hours, were held with participants from industry and academia. Workshops were performed to examine and validate the overall findings of the research, followed by internal academic meetings. The first workshop was held after the literature and document study took place. Here, only the relevant outcomes from the workshops relevant to this study are presented in Table 2.

Table 2. Workshops and relevant outcomes for this study.

Place	The Relevant Outcome of This Study
2 December 2020 TEAMS	The identified set of activities is sufficient for the data collection. It covers all main activities in the pre-construction phase. No need to add more.
13 October 2021 Oslo	The activity approach should be stepwise, and the activities should be split further as the work progresses. The set of activities is too general. Contractor competence vs. contractor involvement is not the same. BIM is important for activity 18.
15 December 2021 Trondheim	The need for competency and the dependencies between the activities should decide how we split the general activities. Soft skills are an issue as they are difficult to measure and control within the different activities.
24 February 2022 Kristiansand	Risk assessment and competency needs should decide how we split activities in the pre-construction phase. Experience with make/buy analysis, i.e., decisions based on economic theories, but it needs a supplement.
25 May 2022 Oslo	The correct way of splitting activities can show dependencies we were not aware of. Impact on criticality activities. Risk assessment is not sufficient. Uncertainty needs to be moved to cover the entire process in addition to an individual activity.
5–6 October 2022 Oslo	It is still possible to mitigate risk when proper splitting is performed as it visualizes the dependencies. Sufficient with a set of activities. Too many activities can become messy.
14 December 2022 Bodø	Difficult to predict all activities when doing refurbishment work. Contractor input is valuable as refurbishment work usually requires upgrading existing structure and there are practical considerations to consider.

3.4. Data Analysis and Iteration of Results

Several steps were taken in the data analysis process to gather and analyze the collected data. The process was performed in accordance with the steps described by [51].

First, the findings from the literature and document study yielded a large pool of activities in the pre-construction phase. Due to the complex nature of infrastructure projects, the set of activities identified was of varying importance, length, and character. Several of the activities were overlapping, so a gap and comparison analysis was performed to categorize different activities and identify which activities could be grouped and combined. Findings were discussed and verified during internal academic meetings and the first workshop. The outcome was used to develop an interview guide.

Thereafter, the points extracted during the interviews were coded for different attributes relevant to the research question. During the coding, different themes and categories had higher frequency due to their importance and occurrence. These were considered of high importance and were, therefore, left open to be discussed and validated through the workshops. After the six workshops were finalized, the findings were again analyzed and interpreted, so the main findings and answers to the research questions were concluded through an extensive iteration process and internal academic discussions. Figure 4 shows an overview of the research process.

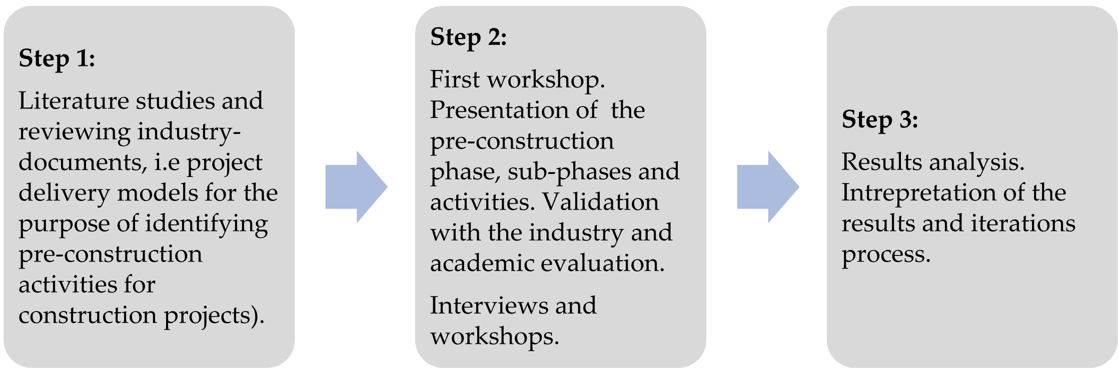

Figure 4. Research design process.

4. Findings

4.1. Pre-Construction Activities

The first research question concerns identifying the main pre-construction activities for public infrastructure projects. The initial literature and document studies identified imprecise language, where phases and sub-phases in pre-construction are used interchangeably, an example being the planning sub-phase that covers different activities in different studies. The research also shows an inconsistency in the terminology, where activities, tasks, and steps are used interchangeably.

The OECD report shows how the scope of work can be clustered into activities according to different economic theories. Some of the activities are on a single-task level, whereas some are long and interdisciplinary activities. An example is from the design sub-phase activities, where road lighting design is equal to bridge design and environmental studies. The 200 activities identified by FHWA show that the pre-construction phase is time-consuming and comprehensive and that the activities in the pre-construction phase can be split further and further. The PDRI tool presents sheets of activities that later can be weighted and a quantitative assessment can be performed. Both the OECD and PDRI tools are working on a more detailed set of activities that can be grouped into different sub-phases and activities. The same goes for NCHRP. (Note: The OECD activity analysis yielded 78 activities across the design, construction, operation, and maintenance phases, and the early sub-phases are not considered.) Public infrastructure projects are exposed to strict legalization and need for political approval, so identification of activities that can overlap or be performed in parallel is valuable as it is both time- and cost-saving. Comparing Neste Steg with different sub-phases identified during the literature studies and different industry project delivery models, the sub-phases identified by Neste Steg framework (strategic definition, brief development, concept development, and detailed design) are considered to include all sub-phases in the pre-construction phase. Using the sub-phases as a base, additional studies were performed to identify the main activities belonging to the four pre-construction sub-phases. Figure 5 shows the outcome of these studies and how phases and sub-phases are defined.

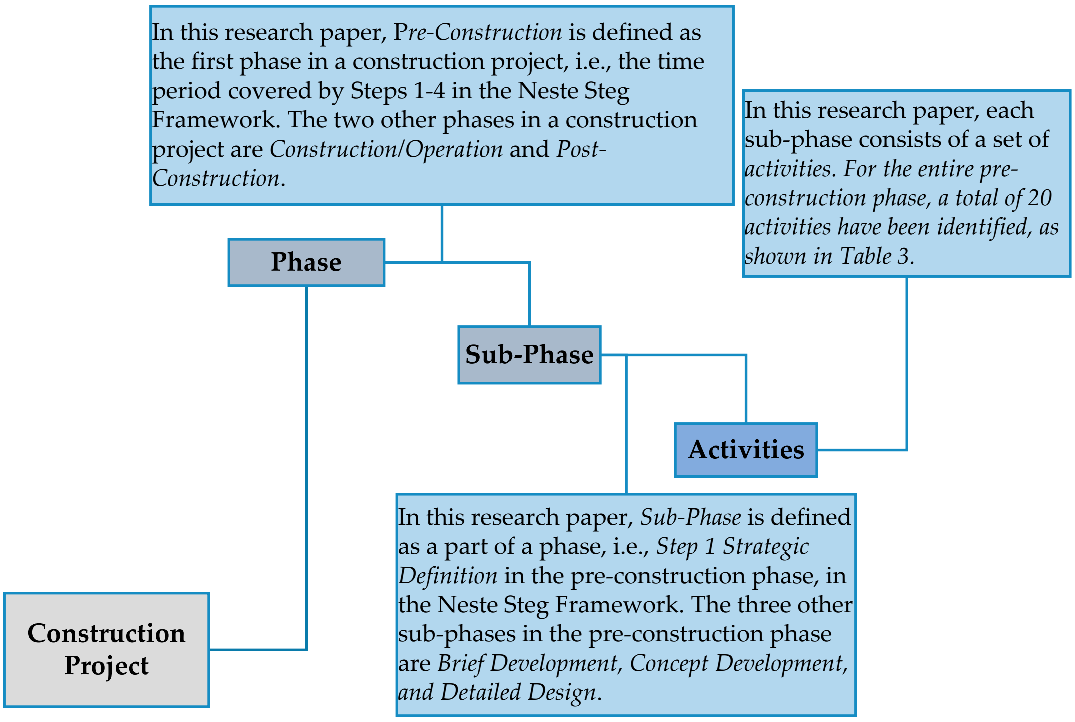

Figure 5. Overview of different project phases and sub-phases.

Findings from the literature studies, workshops, and internal academic meetings were compared, and twenty main activities were identified.

The activities were confirmed during the interviews (the interviewees did not add any additional main activities but pointed out the necessity to split the activities further/detailed work breakdown structure to reflect the actual workload). The 20 identified activities, with belonging sequence and color-coded sub-phases, are shown in Figure 6.

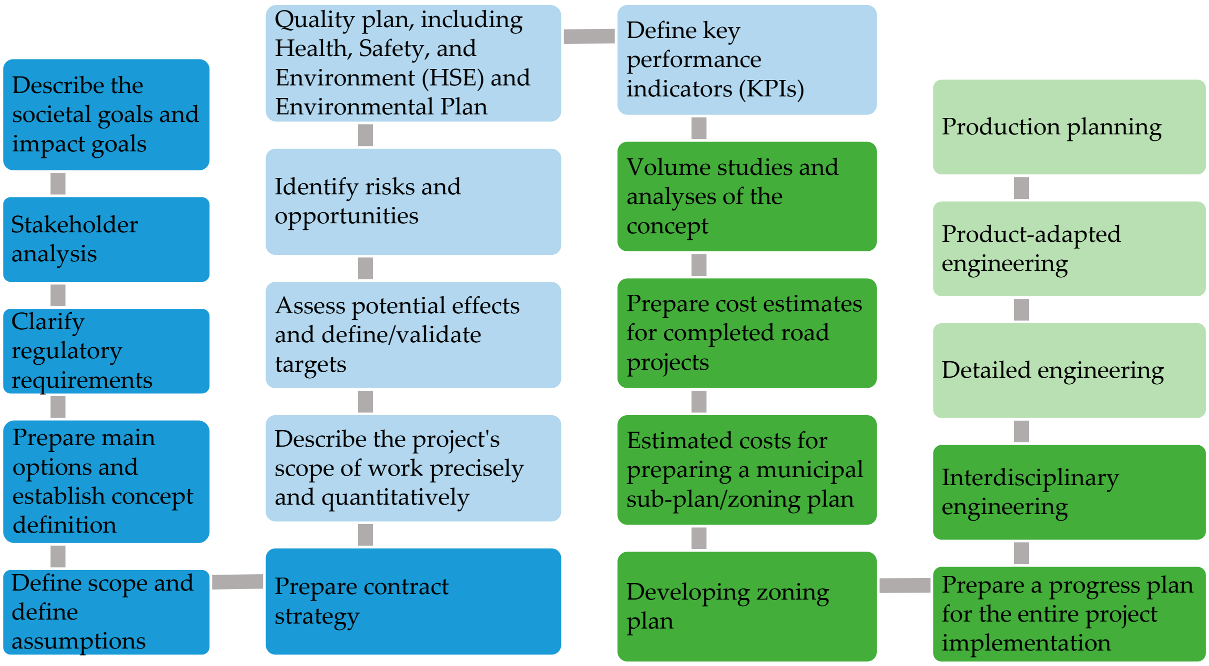

Figure 6. Twenty pre-construction activities color marked. Dark blue is sub-phase 1: Strategic Definition, light blue is sub-phase 2: Brief Development, dark green is sub-phase 3: Concept Development, and light green is sub-phase 4: Detailed designing.

In more detail, the 20 activities are presented in Table 3. The list includes one activity specific to Norway, which is presented in Table 3. The zoning plan activity is split into two separate activities (activity number 14 and 15, the zoning plan, and the cost of the zoning plan). The division is due to the Norwegian state model for quality assurance, which requires the activities to be separated for proper monitoring and assessment.

Table 3. Twenty main pre-construction activities were identified for public infrastructure projects and categorized into Neste-Steg sub-phases. Sub-phase 1: Strategic Definition; sub-phase 2: Brief Development; sub-phase 3: Concept Development; and sub-phase 4: Detailed design.

Neste Steg Sub-phase	Number of Identified Activities	Identified Activity (What to Do?)	Activity Description (How to Do It?)	Activity Justification (Why Do It?)
1	1	Describe the societal goals and impact goals	This activity is a basis for decision-making throughout the project.	The activity covers social and community objectives that projects aim to achieve.
1	2	Stakeholder analysis	This activity is a process where the interests, needs, and impact of different stakeholders are identified and assessed.	Stakeholders are classified according to their level of interest and influence.
1	3	Clarify regulatory requirements	This activity is used to identify and assess various laws and regulations that apply to the project.	It determines how laws and regulations will impact the project's cost, schedule, and feasibility.
1	4	Prepare main options and establish concept definition	This activity covers identifying and evaluating different solutions and construction options for the project.	It aims to evaluate the main options based on the project's goals and constraints.
1	5	Define scope and define assumptions	This activity delineates the project boundaries, including key objectives and goals, while also identifying underlying factors that could impact various project elements, like cost, quality, and schedule.	It aims to enable a thorough understanding of the project's main objectives and potential constraints, fostering a proactive approach to managing unforeseen challenges.
1	6	Prepare contract strategy	This activity is a process of establishing a plan for developing, negotiating, and executing contracts for a construction project.	The aim is to ensure that the type of contract that will be used for the project is suitable.
2	7	Detailed scope of work	This activity develops a precise and quantitative description of the project's scope, focusing on specific tasks and deliverables, including identifying necessary resources and materials.	It aims to facilitate accurate planning and resource allocation, which is paramount in a complex construction landscape, ensuring that the project can meet its objectives without resource constraints.
2	8	Environmental and stakeholder impact assessment	This activity analyzes the potential effects the project might have on the environment and community, including validating targets and defining strategies to mitigate negative impacts.	It aims to support responsible project development within the industry's stringent environmental and societal considerations, ensuring that all potential impacts are assessed and mitigated.

Table 3. *Cont.*

Neste Steg Sub-phase	Number of Identified Activities	Identified Activity (What to Do?)	Activity Description (How to Do It?)	Activity Justification (Why Do It?)
2	9	Identify risks and opportunities	This activity is a process of undertaking a comprehensive uncertainty assessment of the project to pinpoint both potential risks and opportunities and develop strategies for managing uncertainty effectively.	It aims to foster a resilient project management approach, vital in the dynamic construction sector, by early identification and management of risks and leveraging opportunities for better outcomes.
2	10	Quality plan, including Health, Safety, and Environment (HSE) and environmental plan	This activity is a process of establishing separate plans for HSE and environmental planning in the construction, maintenance, and operation phases.	The goal is to ensure that the projects are completed to a high standard of quality and safety and that they minimize harm to the environment.
2	11	Define key performance indicators (KPIs)	This activity identifies metrics that are used to measure the performance of a business or organization against specific goals and objectives.	The goal is to use KPIs to track progress and evaluate the success of the project in achieving its goals.
3	12	Volume studies and analyses of the concept	This activity is a process where the design and technical aspects of the construction project are examined and evaluated.	The purpose is to determine the feasibility of the project and to identify potential issues and constraints that may impact the project's success.
3	13	Preliminary cost estimates	This activity creates an initial cost approximation for the project by assessing the scope of work, material requirements, and labor necessities.	It aims to ensure financial feasibility and helps to secure appropriate funding, a critical step within Norway's prudent fiscal management framework for infrastructure projects
3	14	Municipal sub-plan/zoning plan cost estimation	This activity develops detailed cost estimates for preparing municipal sub-plans and zoning plans, considering the size and complexity of the designated area.	It allows for accurate budgetary planning in line with local government regulations and guidelines, fostering smooth transitions through the zoning and planning phases, a necessity in the well-regulated construction sector.
3	15	Developing zoning plan	This activity is a process of creating a plan for the use and development of land within a defined geographic area.	The goal is to regulate land use and development, so it aligns with the overall goals and objectives of the municipality.
3	16	Prepare a progress plan for the entire project implementation	This activity is a process of creating a comprehensive plan that outlines the steps and milestones that must be achieved to complete the project successfully.	Activity is critical for good project management as it aims to produce a progress plan that shows risky activities, milestones, dependencies, and slack.

Table 3. *Cont.*

Neste Steg Sub-phase	Number of Identified Activities	Identified Activity (What to Do?)	Activity Description (How to Do It?)	Activity Justification (Why Do It?)
4	17	Interdisciplinary engineering	This activity facilitates the collaboration of various engineering disciplines to integrate diverse expertise in the design and development phases of the project.	It requires the participation of engineers from different specialties to work together as it aims to develop solutions to complex problems.
4	18	Detailed engineering	This activity is a process of refining the project's design and developing specific solutions for each aspect of the project.	The goal is to ensure that the design of the project meets the project's objectives, and constructability and complies with codes and standards.
4	19	Product-adapted engineering	This activity is a process of customizing or modifying a product to meet specific requirements.	It enhances project efficiency and effectiveness by tailoring engineering solutions to specific project needs, a strategy aligned with the complex yet flexible spirit of infrastructure construction projects.
4	20	Production planning	This activity is a process of determining what products or services to produce.	It aims to evaluate how much to produce, and when to produce to meet customer demand.

4.2. Pre-Construction Activities That Benefit from ECI

The second research question looks for the main pre-construction activities that can benefit the most (and the least) from ECI. The importance of the activities is based on 22 semi-structured interviews, supplemented with findings from the workshops and group interviews with HENT. Table 4 presents the top 5 and bottom 5 activities identified. The top 5 activities are presented in order of importance, i.e., Activity 9 is the activity that is identified as the one that benefits the most from ECI, whereas the bottom 5 activities are in order of least importance, i.e., the last activity (Activity 1—Describe the societal goals and impact goals) is the activity that is identified as the one that benefits the least from ECI. In this section, the top 3 out of the top 5 activities are elaborated because of the nature of the research question. In addition to that, the main findings for the 5 bottom activities and the 10 other activities are briefly presented to verify the main findings belonging to RQ1.

Table 4. Top and Bottom Activities for ECI identified.

Top Activities for ECI	Activity Description	Bottom Activities for ECI	Activity Description
Activity 9	Identify risks and opportunities	Activity 4	Preparing main options and establishing concepts definition.
Activity 16	Prepare a progress plan for the entire project implementation	Activity 2	Stakeholder analysis
Activity 10	Quality plan, including HSE and environmental plan	Activity 5	Defining assumptions and defining the scope
Activity 12	Volume studies and analyses of concept	Activity 14	Municipal sub-plan/zoning plan cost estimation
Activity 7	Detailed scope of work	Activity 1	Describing the societal goals and impact goals

Activity 9 is nominated as the activity that can benefit the most from ECI. Clients see the value in the practical knowledge the contractors have, especially as related to previous experience. An overall belief is that the contractors can decrease the stakeholder conflict because of their previous experiences and foreseen potential conflict. One of the respondents believes that: 'Because of contractors' knowledge of new technology and machinery, contractors have different construction methods for the same task. This can address the safety issues on site. Another respondent emphasizes that: 'Contractors can contribute to better time- schedule and cost estimation'. Consultants believe that it is crucial to have the contractor involved here, but since the contractors do not want to lay all the cards on the table so early, they believe there is an ethical perspective here. One of the respondents points out: 'It will be wonderful if the contractors share everything, but what is it then in for the contractor then?' Another says that 'Norwegian contractors are good in using the risk tool. Identify opportunities and see overall risk'. At the same time, the same respondent believes that confidential information could be difficult to share and that 'international and Norwegian contractors have different ways of looking at risk'. Contractors identify this activity as a key success area. Contractors mention everything related to market knowledge, cost, time, constructability, and on-site logistics. One contractor claims: 'No one wants to pay for mistakes so this needs to be regulated', whereas another contractor claims: 'Everything is risk and opportunities'. He further elaborates on that: 'Good ideas and different solutions related to planning and scheduling' and 'Ability to interpret available data related to ground conditions that can be converted into solutions'.

Activity 16 is identified as the second activity that can benefit the most from ECI. Clients overall commented that the contractors were best suited for the task. They elaborated further that the contractors can evaluate the timespan, manhours needed, competencies needed, and dependencies between different activities. The practical knowledge the contractors have related to construction methods, site preparation, and HSE among other things, is unique. One of the respondents from the client side commented that: 'The execution competencies including logistics, ability to optimize the logistics and prioritizing activities considering logistics challenges' was what made contractors stand out'. Consultants believe that contractors' input is valuable as the master plan is made early and the plan is constantly revised. In addition, everything happens fast at the construction site, changes need to be dealt with, and one must be prepared that when the execution of the construction phase starts, the planning performed during the pre-construction may be no longer valid. Contractors were confident in their first-hand experience and knowledge they have, and that a progress plan must reflect real work done. For that, they evaluated the contractors to be the most capable of the task. One of the respondents believed that the contractors were the only ones who could 'see and understand the connection between the different tasks and packages- and what those required in terms of time and resources.

Activity 10 is nominated as the third activity that can benefit the most from ECI. Clients believe that the strict and rigid legalization in this area makes this one of the challenging activities. The contractor's technical knowledge highly impacts how the possibilities within the legal framework can be used. In addition, they believe that some situations may be evaluated and avoided early on. There is no intent to <deviate> from the HSE regulations, but rather minimize the risk. Consultants believe that contractors should be more involved in this activity from early on. Different construction methods can have an impact, and local knowledge is important. Sometimes there is a big gap between what the contractors should do and what they are doing, so this is a way to make sure that the contractor does not ignore the situation. Contractors believe that this is solely their job, although it is known that the clients usually use consultants for the preparation of the environmental plan. Local knowledge and site knowledge are important. One of the respondents commented that this activity requires knowing the different risks associated with each activity which is impossible for those without practical knowledge to comprehend.

Main findings—Bottom Activities. Activity 1 is identified as the activity to benefit the least from ECI. There was an overall agreement between the consultants, clients, and contractors that this specific activity does not benefit from ECI. Most respondents answered 'No', leading to no grading. Few commented on the reason, the main reason being that if anyone should be involved besides the client, it should be the consultants to clarify purposes. One of the respondents from the client side clarified that this is a 'political question about what kind of society we want' and not the right time for other ambitions. Though, interestingly, one of the contractors pointed out that 'societal goals are something we traditionally are not involved in but should be. It will not only lead to a better understanding of time and cost, but a commitment. What we do is so much bigger and has an impact on people and the environment'. Activity 14, municipal sub-plan/zoning plan cost estimation, had similar responses as Activity 1, but the difference here was that it came with a note. The client identified if the zoning plan was not approved, the contractors could come with inputs as different solutions led to different costs. The contractor and consultant agreed that Activity 14 could not benefit from the contractor's competence, although it is an important activity in the Norwegian context. In addition to the two, Activities 2, 4, and 5 were identified as activities that benefit the least from ECI, although there are some exemptions. The consultants mentioned that neither they nor the client has the knowledge that is practical enough.

Main Findings—All Other Activities. The 10 other activities, which did not end up as top or bottom activities, received scattered grading and comments. In this bundle, four major engineering activities are found. Some of the respondents from the client side gave these activities the highest score, commenting that although these activities require academic and theoretical knowledge that the client and the consultant can provide, they miss the practical aspect. The constructability question is the biggest challenge. If any changes occur in the design and thereafter during the engineering phase, the contractors can contribute with new solutions when it comes to installation methods, materials, and logistics. On the other hand, some of the respondents from the client and consultant side gave low scores to these activities as they believe that when it reaches the engineering phase, most of the issues are clarified. Here, knowledge of regulations and standards is important, and consultants and clients can consult with the contractor when and if needed. In addition, they are reluctant when it comes to involving contractors as they may make unnecessary changes right before the construction starts. Consultants agree with the constructability aspect and admit that the contractors see solutions the consultant does not see because of their experience in the field. Contractors can also evaluate what can wait and what cannot. Contractors believe that few can match their practical knowledge and that they have a lot to contribute. Both the client and consultant strongly agree that these activities require a high level of teamwork, outstanding communication skills, trust, leadership, openness, and transparency. These findings are in coherence with the observations made by Järvenpää et al. [26].

The overall findings show that the respondents believe that certain activities can benefit the most from ECI, whereas there are activities that can benefit the least from ECI. In addition, there are ten activities that are in the middle, several of them being engineering activities. The findings are from the client's perspective and supplemented with contractor and consultant input.

The nature of the pre-construction activities can be classified into four major systems, as identified by Al-Reshaid et al. [29]: namely, scheduling, cost, financial and administration, and engineering systems. This grouping into categories does not consider the many dimensions different activities have, i.e., Activity 3, which can be considered a legal activity (administration and engineering) but has its roots in both financial and scheduling. The four systems are therefore a simplified visualization but aim to show the complexity of the pre-construction phase and the many various fields it covers.

When considering the nature of activities that were identified as those that benefit the most from ECI, a simplified classification can be that they are mainly planning, environmental, and technical activities related to the clarification of the scope of work (administration and engineering system). Findings from interviews show that the clients are open to input and the practical knowledge the contractors can contribute, especially concerning the top activity related to uncertainty and opportunities. Practical knowledge is mostly related to constructability, installation methods, and knowledge of suitable materials. The contractors mentioned that traditionally the contractors join projects when the work has reached sub-phase 5 (Production) in Neste Steg, but that the decisions controlling the success of sub-phase 5 (Production), are sub-phases 2 (Brief Development) and 3 (Concept Development). An example was the sub-contractors that could have monopolism over material components and technical solutions. These choices could be extremely cost-driving, although other equally good solutions were available. The consultants are somewhat more reluctant as they believe that the contractors withhold important solutions, ideas, and possibilities, as they have little to gain by sharing it all early. The three parties agree somewhat more on the activity related to the quality plan and environmental plan along with progress planning. Here, they agree on the contribution the contractors have because of their practical knowledge and previous experience. The consultants also mention that involving the contractors here will make them more aware of these requirements and hold them more accountable.

5. Discussion

5.1. What Are the Main Pre-Construction Activities for Public Infrastructure Projects?

When addressing the first research question and the main activities in the pre-construction phase, there is a consistency in the activity findings from the literature and document studies. Here, document studies consist of documents belonging to all six industry partners and the deliverables from Neste Steg. Input from interviews regarding the set of activities and testing during the workshops showed that a top-down approach, which the authors identified and named a layered approach for identifying activities, is appropriate. This layered approach to identifying activities led the authors to come up with a shell model, as presented in Figure 7.

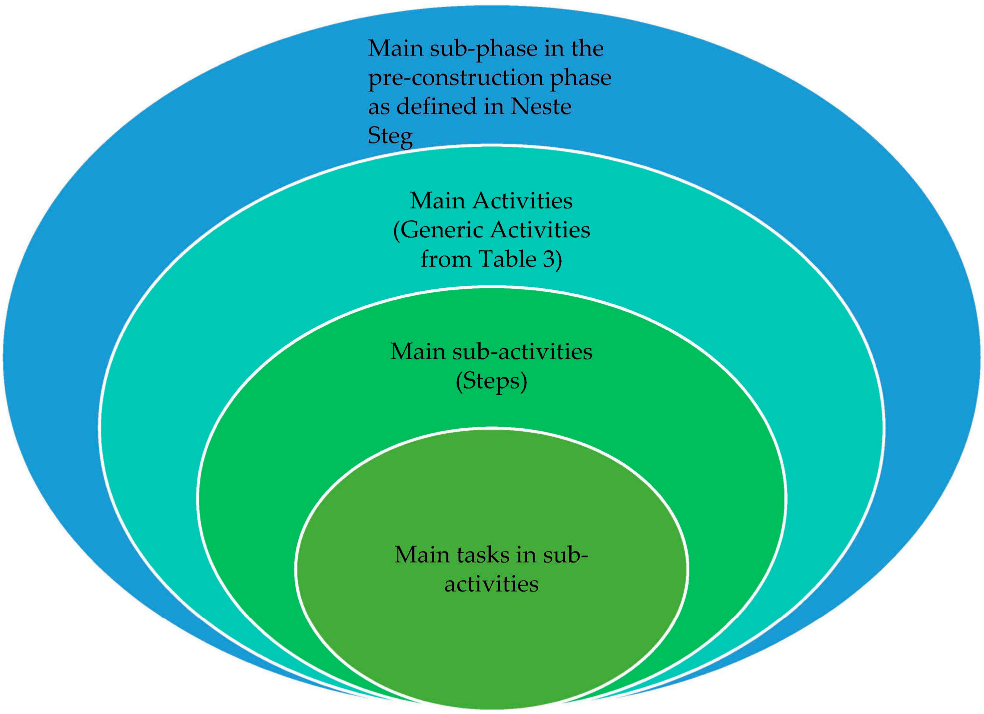

Figure 7. Shell model for pre-construction.

It is a model that can be used to systematically break down the pre-construction phase. The process starts with the different sub-phases in Neste Steg, as presented in Figure 1. In the layered approach, the first step is to start with the relevant sub-phase and generic activities and continue splitting into sub-activities where needed, i.e., where the scope, duration, complexity, cost, etc., implies that it is needed.

The shell model consisting of four shells sums up the findings and presents the built-up for activity identification. Neste Steg sub-phases (strategic definition, brief development, concept development, and detailed design) represent the outer shell (4th shell). The third shell represents the identified generic activities, which is the first step toward detailing the sub-phases and categories that need to be covered. The second shell represents the further splitting of an activity, defined as a step, and last, the inner shell (1st shell) represents a single task in that step. In more practical terms, an example would be detailed design (sub-phase)—detailed engineering (activity)—structural engineering (step)—concrete calculations (task).

Figure 8 shows that there is no limit to how many activities one can identify in a sub-phase, steps in an activity, or tasks in steps. This recipe for identifying and establishing a suitable work breakdown structure is also a result of the inputs gained during the workshops, see Table 2. The 20 activities were too general but valuable as they gave a starting point and made it possible to collect valuable data, whereas the set of activities identified by both CII and OECD were detailed and structured but too comprehensive to evaluate. In the transition from Figure 7 to Figure 8, both the STEPS tool and PDRI tool can be used to identify steps and tasks belonging to the main activities and sub-phases as findings from workshops identified STEPS (nominating make-or-buy activities based on economic theories) as a solution to considering ECI. The degree of detailing will depend on the PDRI application points as stated in CII. The maturity of the work will be reflected in the ability to identify tasks as the work progresses. The model in Figure 7 can therefore be used in point 1 as shown in Figure 2 and the model in Figure 8 can be used for PDRI application points 2, 2i, and 3 in Figure 2. More precisely, Figure 8 is an in-depth explanation of Figure 7, showing that there is an 'unlimited' number of activities and tasks to be identified.

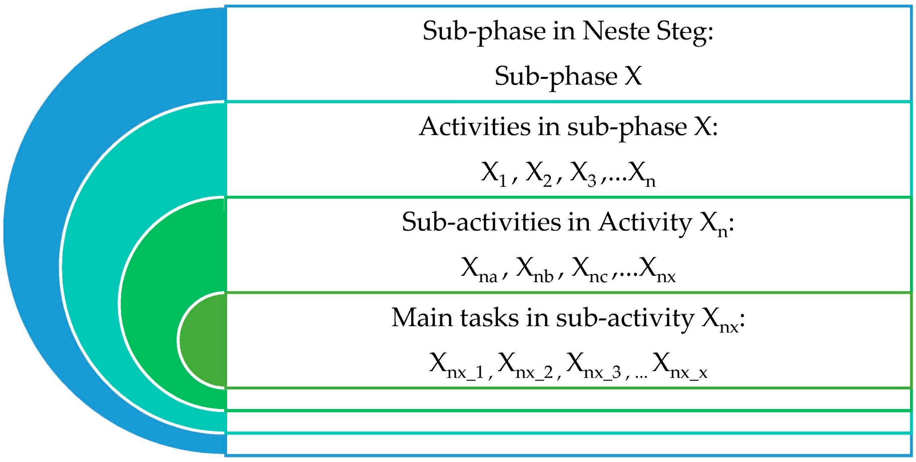

Figure 8. Shell model work breakdown structure.

The main advantage of the shell-model approach is splitting up a long and comprehensive phase into manageable activities. A disadvantage is uncertainty related to the splitting itself, i.e., at what layer it is appropriate to stop the splitting of the activities? When certain activities are split into several tasks, it may lead to less overview of the work needed to be performed. Splitting up activities at a suitable level contributes to easier connecting the work process and the aim with the project. This is relevant, especially for refurbishment work as identified during the Bodø workshop where solutions are supplements to the already existing structure.

5.2. Which of the Main Pre-Construction Activities Can Benefit the Most from ECI?

When addressing the second research question, it is seen that the top 5 activities show that the end of sub-phase 2 in Neste Steg is believed to benefit the most from ECI. These findings are to some degree aligned with the literature findings where involvement in the conceptual sub-phase contributes to desirable possibilities [45] and findings from interviews with contractors who identified sub-phases 2 and 3 as the sub-phases that control the success of sub-phase 5, as also indicated by Sarbini [46]. When evaluating these activities, one can see that planning and environmental activities are not stand-alone activities but are directly linked to the technical solutions available. Planning is directly related to the work breakdown structure and sequence, and the dependencies between the technical tasks and environment are related to different technical solutions and materials associated with different technical tasks. The 5th activity on the top 5 list that can benefit the most from ECI is the first purely technical activity. The other engineering activities are in the pool of <other> activities that are found in the middle. These 10 activities, which are neither top nor bottom, show that there is a high degree of scattered grading and comments. Whereas the contractor's practical knowledge is the main explanation for almost all activities, pure technical activities are not found at the top. Indications for the reasons can already be found in the top activity where there is an assumption that the contractors will not show their cards early whether they are involved or not. These findings align with the literature where respondents identified constructability as the most important contribution from the contractors to the design [54]. Contractors have valuable product information from previous projects, including technical products and materials, so carefully sharing their knowledge is in their favor as the main goal for contractors is to assume profit. Clients should compensate contractors properly to ensure that the contractors share their knowledge with the client [55]. Findings show that there is a fear of contractors making unnecessary design changes, especially later in the construction phase when most of the main design is frozen. Clients mention teamwork, leadership, trust, and transparency as requirements to perform technical activities. The contractors, on the other hand, believe that the technical activities are activities where they can contribute the most and where the real work starts for them. When asked to elaborate on why clients emphasize relational skills, one of the contractors answered: 'I don't know why they think we want to fool them. When working together we become colleagues and we all want work-life balance'. Another contractor mentioned: 'I understand the expectation of cost-saving, but at the same time I don't. ECI is not necessarily about cheaper solutions, it is about better solutions, and we are better together'. This aligns with the findings from van der Walt et al. [14] where the timing/what activities contractors should be involved in is different for different stakeholders. Still, it also indicates that the clients are careful not to share too much with the contractors. This can be directly linked to the risk/opportunity activity and the impact it has on cost and time. Results from the interviews may indicate that there is an ambivalent relationship when it comes to the early involvement of contractors. Although there is a common understanding that the benefits are high and that the highest impact contractors have is in the conceptual sub-phase and during the design/technical clarification, the highest-scoring activities indicate that there is a significant dispersal between the clients, consultants, and the contractors. In Neste Steg terms, the literature identified sub-phase 2 as the most beneficial time for ECI in terms of design improvement, innovation, safety, cost, and time and sub-phase 3 as the most vibrant for technical solutions, whereas findings from interviews and workshops identify sub-phase 2 as the most beneficial time but do not identify any of the technical activities (late sub-phase 3 and sub-phase 4) as relevant for ECI. These findings are in contrast with findings by Wang [6] who concluded that between the planning and design phases, the client should actively promote ECI as it breaks contractors' traditional passive acceptance mode and replaces it with a win–win, mutually beneficial cooperation mode. A similar is supported by Lappalainen et al. [5] who suggest that the earlier a contractor gets involved in the design, the more the quality of the design can increase.

When considering the nature of activities that were identified as those that benefit the least from ECI, a simplified classification can be that they are mainly social and political activities, i.e., they are based on political processes and approvals as they directly impact society. These activities come somewhat early in the pre-construction phase where little is known and clarified. Here, the client does not see it as suitable for others to get involved. In some cases, they could use the consultants for clarification purposes, but the scope belongs to the client. The consultant and contractor's views are consistent with the clients. These activities can be defined as *framework activities* as the project processes are guided by them. These activities mainly belong to the group's (1) vision, mission, and goals, as defined by Chinowsky and Meredith [33]. Another observation is that activities 4 and 5 score low, whereas activities that are directly dependent on them, such as activities 7,9,10, and 12, are among the top five. These findings are in contrast with the findings by Naoum [44] and Ferme et al. [34] who acknowledge the importance of the early involvement of stakeholders for the sake of achieving value. The achievement of the intended value (both short-term goals and long-term goals). With regards to the external stakeholder groups as defined by Gaur et al. [3], the activities impacting them are activities with the lowest score when considering ECI benefits. Although CII identified that infrastructure projects have extensive interfaces with the public, the involvement of key stakeholders, such as the contractors, is not considered relevant.

Figure 9 shows how the identified activities in the pre-construction phase in Neste Steg are distributed according to which activities benefit the most from ECI. Red indicates no involvement; green is suitable for involvement; and yellow is neutral. Activity 14, which is on the top-bottom list, is not included in Figure 9 as it is a Norwegian-specific activity, as mentioned in Section 4.

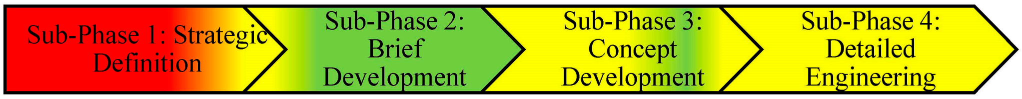

Figure 9. Neste Steg pre-construction sub-phases and color-coded ECI-relevant activities.

Figure 9 shows that sub-phase 2, Brief Development, is considered as the time during the pre-construction phase that benefits the most from ECI, whereas sub-phases 3 and 4 have gained dispersed results, with contractors considering sub-phase 3 and 4 as the time contractors can contribute the most. Sub-phase 2 is traditionally managed by clients, with some input from consultants. The clarifications are on a higher level where the clients still control the process, compared with the next sub-phases, and several of the nominated activities are of less strategic importance. Findings indicate that there is still a high degree of uncertainty in the client organizations regarding how to approach and make use of ECI for innovative and technical solutions. For certain activities, the client and the consultant want the contractors to guide them and give them enough input and support but not allow them to make changes independently, i.e., involve the contractors in strategic activities where they can have a larger impact, so-called framework activities. The clients acknowledge the valuable contribution contractors can add but do not trust them enough to involve them where it makes the most impact (activities belonging to the vision, mission, and goals)—in practical terms, activities that control the project process.

In this study, it is important to acknowledge several limitations that may have influenced the findings and should be considered when interpreting the results. These are mentioned in the Introduction Section. In addition to the number of respondents, one apparent limitation lies in the fact that the results are derived from the Norwegian construction industry and influenced by the cultural context of the construction industry in Norway. However, we believe that despite these specific contextual factors, the findings possess a degree of generality and applicability to the construction industry overall.

6. Conclusions

The aim of this paper was to (1) identify the main pre-construction activities for public infrastructure projects and (2) identify which of these main pre-construction activities can benefit the most from ECI. The findings are based mainly on the client perspective, substantiated by the contractor and consultant perspective.

The findings concerning the first research question identified twenty pre-construction activities for public infrastructure projects after comparing the existing literature, Neste Steg deliverables, and different project delivery models from six industry partners. During the interviews, the interviewees confirmed that the set of activities covered the main parts of the pre-construction phase but that additional splitting up may be necessary when evaluating a pre-construction phase of an infrastructure project. The participants during the workshops acknowledged the benefit of having a specific set of activities that was not an overwhelming quantity, making it possible to split these activities further. This logic led the authors to come up with the *layered approach* to activity identification (shell model), as presented in Figures 7 and 8. This approach contributes to an appropriate splitting of the pre-construction phase by offering a four-layered approach to identify the scope of work that can be combined with established tools, such as PDRI. This is a more structured way of mapping the pre-construction phase, resulting in a consistent working method that makes it possible for different project participants to find common ground for further work.

The findings concerning the second research question identified that those activities that benefit the most from ECI are planning, environmental, and technical activities related to the clarification of the scope of work (administration and engineering system), as grouped by Al-Reshaid et al. [29]. The top identified activity was related to uncertainty (risk and opportunities), where the clients stated that the contractors can use their practical background to identify and foresee issues and opportunities that can arise. Clients see the value in the practical knowledge the contractors have, especially related to previous experience. The second highest activity was related to planning where contractors' practical knowledge provides a specific insight into activity dependencies, and the third highest scoring activity was related to HSE and environmental plans, i.e., strict and rigid legalization where the contractor can help the client to navigate.

The overall findings show that the clients acknowledge the valuable contribution contractors can add but do not trust them enough to involve them where it makes the most impact (activities belonging to the vision, mission, and goals)—activities that control the project process. The client and consultant want the contractors to guide them and provide input but do not allow them to make changes on their own. This is seen from the nature of activities that were identified as those that benefit the least from ECI. These are classified as mainly social and political activities—i.e., they are based on political processes and approvals as they directly impact society.

The consultants especially emphasize trust and openness as the challenges when working closely with the contractors. There are activities where the three sides agree that it is not beneficial to involve the contractors, but to some extent, the three sides still see their benefit and strategy before the good of the project.

Contribution

The overall findings in this research paper show that ECI should not be treated as an umbrella term. Involving the contractors during the pre-construction phase is indistinct as there are possibilities to split the pre-construction phase into a set of activities and numerous sub-activities/tasks, depending on the project and the motive for involvement. The twenty identified activities can be a starting point for identifying other pre-construction activities and studying which activities need to be carefully examined in different projects. Well-established tools, such as STEPS and PDRI, can be used to further complement and examine the set of main activities, which contributes to a more systematic approach to ECI.

This paper also identified the top five activities out of the twenty activities that industry practitioners consider could benefit the most from ECI and the bottom five.

Further research by splitting these activities can contribute to more knowledge about the different dimensions that activities have. During the workshop discussions, the generic pre-construction activities have proven to be valuable as they create a common ground, linking different industry project delivery models, stimulating discussion on value creation, and contributing to experience exchange regarding ECI.

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