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Can business-driven and climate-based contracting of bridges make us build climate-smarter?

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Abstract

Today, it is not possible to question the construction industry's impact on the environment. Vast amounts of resources are extracted, and high amounts of waste are generated. The energy consumption in material extraction, production of building materials and elements, transport, and construction activities sums up to 15% of the global emissions. The construction industry's market-driven nature and regulatory requirements set by Administration bodies define the playground for implementing activities that aim to reduce climate impact. International industry associations point out that minimising the material volume is a low-hanging fruit and research shows that this is prosperous. Still, implementation is slow.
This paper argues for and discusses three paradoxes regarding why climate-smart work is slow in implementation and how business-driving aspects obstruct building climate-smart. The argumentation is developed from a perspective that the people-profit-planet unity needs to be considered in balance, in general, and that the profit-planet unity needs to be considered in tandem for market-driven and climate-based contracting, especially. Even though it is tempting to say that we should stop building, it is not feasible for a developing Society. The question is how we can design and build smarter.
The conclusion of this work is that the sector needs to address current procurement strategies that are short-term profit-oriented, understand how upstream decisions obstruct climate-smart solutions, and use digital working procedures and tools to leverage the available information in early project stages. At the bottom-line, to make climate a competitive factor in the construction industry is imperative for a climate transformation of the sector.

Keywords: bridge design; construction process; contracting; business-driven; climate-based; build-clever;

1. Introduction

There is no counterargument to that the construction industry heavily impacts our climate - 15% of global emissions, 30% of waste generation, and 50% of resource extraction, according to [1]. Numerous research and innovations try to counteract this impact, with the hierarchy of net zero design from IStructE as one example. Will Arnold's discussion start with reflecting on the actual need for building - Do we need to build? If the answer is yes, we should ask if building less and/or more cleverly, smarter, is possible [2]. Nor is there a counterargument that Society could develop without infrastructure - facts show that Swedish vehicle-kilometre will increase by 0.88% and 1.28% yearly for cars and trucks, respectively [3]. And, it is highly questionable that a road or bridge is built without purpose, as an answer to the first question, but what can we do in order to build smarter? The Global Cement and Concrete Association guide directs us to minimise the material and resources as its part of net-zero roadmap accounts for 22% [4]. Research on optimising structures is vast and apparently prosperous. Rempling et al. show a 15-40% reduction of CO2-eq for commonly used bridges [5]. Despite successful research, there has been slow implementation. This paper discusses climate research and innovations and how the lack of business-driving aspects obstructs building smarter.

2. Method

The empiri is complex and needs to be founded on deep general experience in the industry, ranging from working procedures to business incentives to engineering aspects of design consultancies, public clients, and contractors. The argumentation and discussions presented here are developed during numerous workshops, conversations, and meetings. introducing elements from the field of action research; more precisely concerning the pragmatic change of the empiri, by numerous cycles of reflection and action, as suggested by [6]. The developed argumentation is highly based on John Elkington´s paradoxes on the interrelated dimensions of people, profit and the planet, presented in the book "Cannibals with Forks: The Tripple Bottom Line of the 21st-century Business" [7].

3. Frame of reference

3.1. The climate estimation and declaration of bridges in the Swedish bridge-building process.

In the procurement strategy plan 2023. the Swedish Transport Administration highlight market competition as a means to meet transport system and market development goals. The administration aims to improve its competence in several areas, including setting requirements, using life-cycle perspectives, fostering innovation, setting balanced evaluation criteria, applying bonuses and incentives, and utilising dialogue-based procurement processes. The ultimate goal is to create a more efficient and innovative supplier market that aligns with the broader objectives of the Swedish Transport Administration. On this strategic level, the administration underlines the importance of sustainability in general and contributes explicitly to the interrelated dimensions of people, profit and the planet; the Swedish Transport Administration (Trafikverket), together with suppliers, must be able to drive development through small as well as significant steps, using both known and unknown solutions and methods. Given the size of Trafikverket's operations, great responsibility and significant opportunities come. Trafikverket should be a role model in pushing development forward and be seen as an attractive customer and partner for suppliers [8]. On an operative level, in project contracting, the administration has, during the last decade, developed climate assessment procedures and a tool to perform estimations in a standardised way. Figure 1 presents a theoretical process model of climate estimation and declarations during the building process. The model is adopted from [9]; to distinguish between purposes, the model has been split into two parts: a democratic (orange) and a project delivery (blue). Climate estimations function as gates during the process and should be calculated using the provided tool.

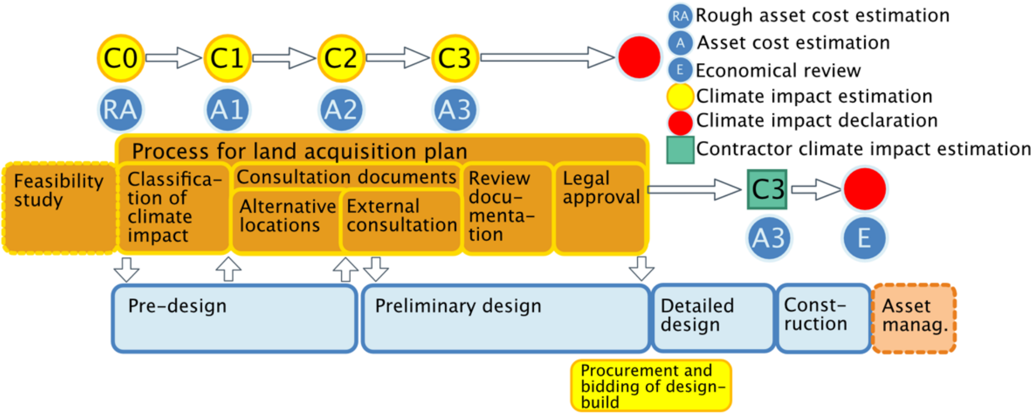

Figure 1: A theoretical process model of climate estimation and declarations during the building process. The model is adopted from [6]; to distinguish between purposes, the model has been split into two parts: a democratic (orange) and a project delivery part (blue).

3.2. Standardisation of a sustainable supply chain

The European Standard *"Sustainability of construction works"* [10] outlines the rules for calculating the environmental performance of new and existing buildings. It is part of a broader set of European Standards, Technical Specifications, and Technical Reports that aim to measure the environmental impact of buildings to support sustainable construction and development. Overall, this standard aims to support the evaluation and decision-making process related to environmental performance in buildings. To standardise the assessment, a boundary principle has been implemented. Boundary modules A1 to C4 cover environmental impacts and aspects that are directly linked to processes and operations taking place within the system boundary of the building, while module D provides the net benefits relating to exported energy and secondary materials, secondary fuels or secondary products resulting from reuse, recycling and energy recovery that take place beyond the system boundary. From a business-driven and climate-based contracting perspective, Boundary module A, the product, transport and installation stages are dominant and considered inherent for climate-effective procurement.

3.3. Public general regulations of climate requirements and contracting

The Swedish Transport Administration is a client organisation assigned by the Swedish government to develop the transport system for all road and railroad traffic in Sweden. Their mission, as stated by the government, is to ensure that the transport systems operate with the highest quality and security [11] and, therefore, the administration plans new mega projects under Sweden's infrastructure development framework [12]. As a result, many international contractors are attracted to engage in these projects. On the Swedish market, Swedish Standard Agreements, AB04 and ABT06, regulate and set up the contracting process. In 2021, a comparative study of the differences between Swedish standard agreements and international contracting agreements, e.g. FIDIC, was performed. The comparison evaluated quality, productivity, and sustainability in AB and FIDIC agreements. The results show a higher level of consideration and application of these factors in FIDIC contracts than in AB contracts. The Swedish AB contracts are perceived as instructive contracts that lack cooperation and collaboration among parties, resulting in poor sustainability focus mainly due to a lack of climate regulatory requirements in the contracting process [13]. The template for bridge contracting makes space for climate requirements but does not prescribe verification methods closer than it should be done by a third party on A1-A3. In the production stage, the contractor must perform climate declarations in the Administration´s climate estimation software according to TDOK 2015:0007, Klimatkalkyl [9]. The project should establish a CO2-eq baseline for assessing climate improvements during construction.

Reinforcement steel and concrete are mentioned specifically with suggested baseline values [14]. The current climate strategy of the Administration is that projects should be benchmarked against delivered infrastructure year 2015. The contract should describe climate bonuses and penalties in the procurement documentation. Values of bonuses and penalties are specified (2023) to 1-1.5 SEK and 2-3 SEK per kg CO2-eq, respectively [15].

3.4. Business- and Climate-driven contracting of bridges in Sweden

There is an increasing need to deal with all aspects of sustainability and buildability within the infrastructure sector. The infrastructure construction process tends to be complicated due to the many actors involved, with separate goals and aims. The actors must understand the vitality of their possibility to impact and the importance of collaboration. A study of the roles and responsibilities concerning sustainability and buildability within the Swedish infrastructure sector, focusing on bridge engineering and early design phases, showed that collaboration constitutes a base for change, where the infrastructure sector requires a better transboundary understanding of the actor's responsibilities. The top project management emphasises the importance of cooperation in improving the work with sustainability and buildability in infrastructure projects. However, even though collaboration is ranked high, profit is the most prominent driving force for change and constitutes the base for creating financial incentives, which the top project management seems to encourage [16]. Still, the procurement strategies of the Administration have a competitive and collaborative focus, according to current examples [8]; one example is given in Figure 2.

Competition focus → Collaboration focus

Form of contract	Design–Build	Design–Build, with cooperation in design	Early contractor involvement
	Design–Bid–Build	Design–Bid–Build, with cooperation in design	
Form of reimbursement	Fixed price, with or without volume regulation	Cost contract with incentive-driven reimbursement	Cost contract with possible fixed price model for contractor
		Innovation and quality bonus	Innovation and quality bonus
Form of evaluation	Lowest–price model	Balanced evaluation of quality and price	Balanced evaluation of quality and price with focus on quality

Figure 2: Procurement strategies from a competition/collaborative focus to a competition/climate focus [8].

3.5. Systems engineering

Compared with many other industries, the realisation of a construction project is subject to more risks due to the unique features of its activities, such as unique functional characteristics, geographic location and absence of industrialised production facility, lengthy development and realisation period, complicated and dynamic construction activities, interferences from opposing parties of interests to name a few aspects. Managing those project risks is meant to control and minimise time delays, cost overruns, functional failures, hazardous situations and negative environmental impacts. The construction industry's traditional trust in craftsmanship has made requirements breakdown, verification, and validation less crucial than in other industries [17]. Despite the identified challenges, Systems Engineering has several potential benefits in construction. Adopting a systems engineering approach in the construction industry intends to achieve objectives like minimisation of risks, improved quality predictability, and improved communication between stakeholders. Digitalisation and new technologies might also enable a more successful implementation [18].

4. Discussion

In the discussion, three interrelated paradoxes argue that implementing climate activities is complex and needs to be discussed from a business and climate perspective in parallel.

4.1. The paradox of climate-drive and business incentives

The market-driven nature of the construction industry is a dominating factor for industry parties and the business paths that the industry parties consider, [19]. Lagerkvist et al. also concluded that there is considerable controversy between short-term profit incentives and climate focus; when asking the industry how important, in ranking, sustainability is for productivity increase, it was ranked severely low [19], Table 2] showing a controversy between productivity increase and sustainability incentives. In addition to the controversy of climate and business incentives, it may be discussed that the state-of-practised business model of hourly-based reimbursement form of design-consultancies, client or contractor contracted, unarms climate-driven designs as the incentives are low to find cost-climate and production effective solutions.

	Competition focus		Climate focus
Form of contract	Design–Build	Design–Build, with cooperation in climate–based design	Early contractor involvement
	Design–Bid–Build	Design–Bid–Build, with cooperation in climate–based design	
Form of reimbursement	Fixed price, with or without volume regulation	Cost contract with climate–incentive driven reimbursement	Cost contract with possible fixed price model for contractor
		Innovation and climate bonus	Innovation and climate bonus
Form of evaluation	Lowest–price model	Balanced evaluation of climate and price	Balanced evaluation of climate and price with focus on climate

Figure 3: Altered procurement strategies from a competition/collaborative focus to a competition/climate focus.

There is a quick fix to this discord of climate and business incentive paradox; one thinking that emerges naturally is that the hourly-rated business model needs to be altered to a business model that is climate-competence focused. In the continuation of that thinking, the upstream procurement strategies need to be altered from competition and collaboration focuses to competition and climate-focused, leading to those sector parties that today practice an hourly rated model needing to cannibalise their business model. A suggestion of altered procurement strategies is presented in Figure 3. As observed, the alteration is not theoretically challenging but might be practically challenging.

4.2. The paradox of regulatory and contracting requirements and market competition for climate-effective solutions

In the last few years, reports have emerged that the decarbonisation rates of steel and concrete will overshoot their yearly targets and not meet the trajectories of 50% reduction by 2030; the British Constructional Steel Association [5] and UK Concrete if the Mineral Products Association [6] indicate a 25% emission reduction, which is not close to the required 50%, and thereby do not confront the fact that the decarbonisation happens too late [1]. The fact is that if you want to cast 100m3 of concrete, it requires 120 tons of gravel, 60 tonnes of sand, 60 tonnes of limestone, and 17000 litres of fresh water [1]. The focus on the supply chain and sustainability has developed with speed and the nowadays well-developed CEN standard "EN 15978 - Sustainability of construction works - Assessment of environmental performance of buildings – Calculation method" [10] has guided national administrations in their work on setting up regulatory requirements to minimise the material usage [20]. On the other hand, the focus on the supply chain has drawn attention from the upstream decisions that settle the playground during the design and production planning stages, leading to an inflexible solution space and a lack of incentives for the construction market to climate-innovate. Here, a paradox develops; the client´s decision during the feasibility study and acquisition plan process impedes the well-intended work with sustainable supply chains. A shift is needed as a complement to the regulatory requirements. A balanced shift that creates space for bidding with climate as a competitive edge, and, therefore, gives incentives to the construction market to develop climate-effective solutions. The regulatory climate requirements should act as a baseline, a maximum climate impact level, on which the market can compete below and be reimbursed as discussed in Section 4.1. A conceptual process map of decision, procurement, bidding and verification is presented in Figure 4: A conceptual process map of decision, procurement, bidding and verification.Figure 4. The Figure incorporates process and an organisational hierarchy concept adopted from the work of TG90 of CIB [21] in a System Engineering perspective according to [17, 18, 22] From a systems engineering process perspective, the hierarchy connects the strategic willingness with project delivery and the engineering developing process by the requirement decomposition and the related verification methods, which are supported by digital tools. The digital tools need to support the decision-making by leveraging the information level early in the process.

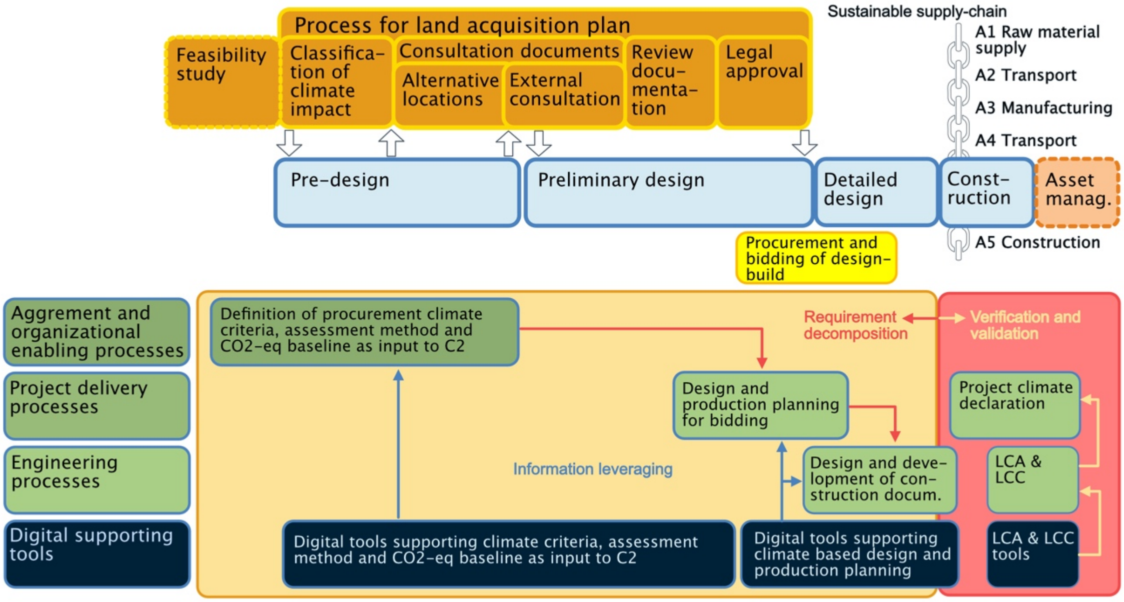

Figure 4: A conceptual process map of decision, procurement, bidding and verification.

4.3. Paradox of information deficiency and climate-effective decision-making in early design stages

In 2004, Patrick MacLeamy drew, based on ideas of [23], the curve of the ability to influence the project outcome the more developed the project becomes. The thinking starts from the idea that in the early phases of a project, the freedom to make design and production choices is large, and as the project design develops, the ability to make changes gets smaller. This logic makes sense and complies with the decision-making that drives the project forward. MacLeamy drew a parabolic curve. However, from a contracting perspective, the curve is rather a series of steps than parabolic or linear, with smaller steps in the beginning, larger steps at strategic choices, such as choice of procurement strategy, and a huge step at the contracting of a contractor. On the other hand, the actual information is low at the beginning of a project, e.g. yearly traffic is known, but the bridge type is not settled. Connecting back to that climate-estimations are information "heavy", a third paradox is formulated *"To make climate-effective decisions early in the process, information of high quality is required. However, the information is poor and lacks precision*." To reach a project stage at which the project is defined with a precision that works as a basis for procurement, decisions need to be made that affect the possibility of influencing the economic and environmental aspects of the project. The need for digital tools and working procedures that increase information levels in the decision-making stages of the process is the way forward. Examples such as [18, 24–27] apply a design method based on [28] evaluating thousands of alternatives to a low design cost. The method, called set-based design, is based on the Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster [29, 30]. In other words, know more, far earlier than you need to make decisions. In Figure 5, the information leverage by set-based design is visualised. The method generates synthetical information used to make climate-, cost- and profit-estimation throughout the project, allowing decision-makers to make data-informed decisions. The method may also be applied to procurement definitions and to define climate baselines and competitive space for bidders. At the bottom-line, to make climate a competitive factor in the construction industry is imperative for a climate transformation of the sector.

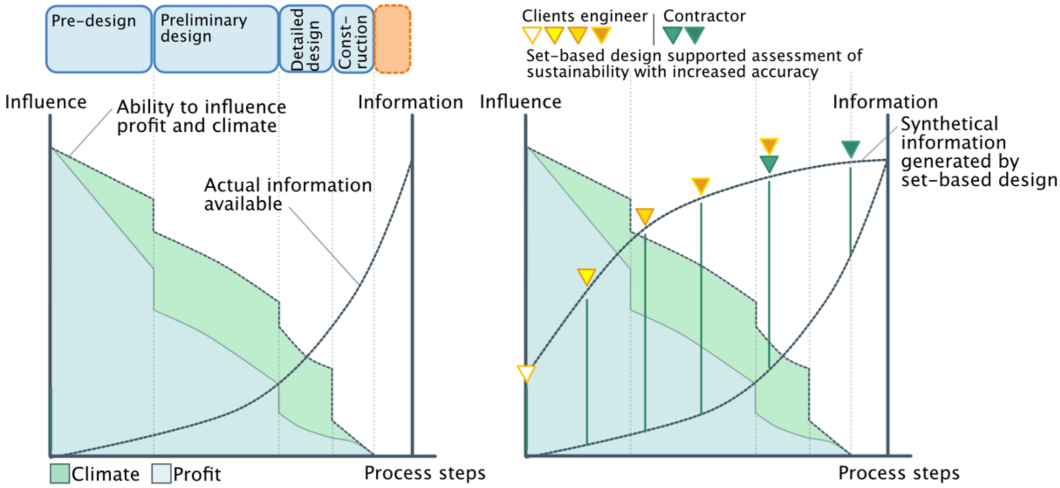

Figure 5: To make climate-effective decisions early in the process, information of high quality is required. However, the information is poor and lacks precision. The set-based design method generates synthetical information that is used to make climate-, cost- and profit-estimation throughout the project, allowing decision-makers to make data-informed decisions.

5. Conclusion

This paper argues for and discusses three paradoxes regarding why climate-smart work is slow in implementation and how business-driving aspects obstruct building cleverly. The argumentation is developed from a perspective that the people-profit-planet unity needs to be considered in balance, in general, and that the profit-planet unity needs to be considered hand-in-hand for market-driven and climate-based contracting, especially. Even though it is tempting to say that we should stop building, it is not feasible for a developing Society. The question is how we can design and build smarter; more clever.

The Swedish Transport Administration's mission, as stated by the government, is to ensure that the transport systems operate with the highest quality and security. During the coming 20 years, the vehicle-kilometre will increase by approximately 1% yearly. To meet that, the administration will invest 80 billion euros (2020-2033). How many of these millions will be climate-smart millions? Research on smart design and construction is vast and apparently prosperous. Researchers have shown that it is easy to reduce material usage by 15-40% in common bridge constructions; still, implementation is low.

We argue that as long as the business-incentives are low, climate-smart solutions will not be the first choice and list three paradoxes that obstruct building smarter:

- The paradox of climate-drive and business incentives
  The profit-planet unity is not considered in tandem, a perspective that is strange due to the construction industry's market-driven nature. Due to the procurement strategies used, short-term profit incentives dominate the sector. To transform, the industry needs to reimburse and procure with a competition and climate focus.
- The paradox of regulatory and contracting requirements and market competition for climate-effective solutions
  The construction industry tends to focus on implementing climate-smart construction where the contribution is highest, i.e., the cradle-to-gate, site, and installation of products; and not on the upstream decision-making that would make it possible to influence the impact.
- Paradox of information deficiency and climate-effective decision-making in early design stages
  Information is needed in the early project stages to business-drive projects on a climate-basis. Mainly, due to that, it is essentially difficult to set procurement base-lines and space market opportunities. Paradoxically, the information is lowest in the beginning. Digital working procedures and tools can increase the level of

information throughout the process; by forming a knowledge-basis for decision-making, it is possible to procure bridges on climate and competition.

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