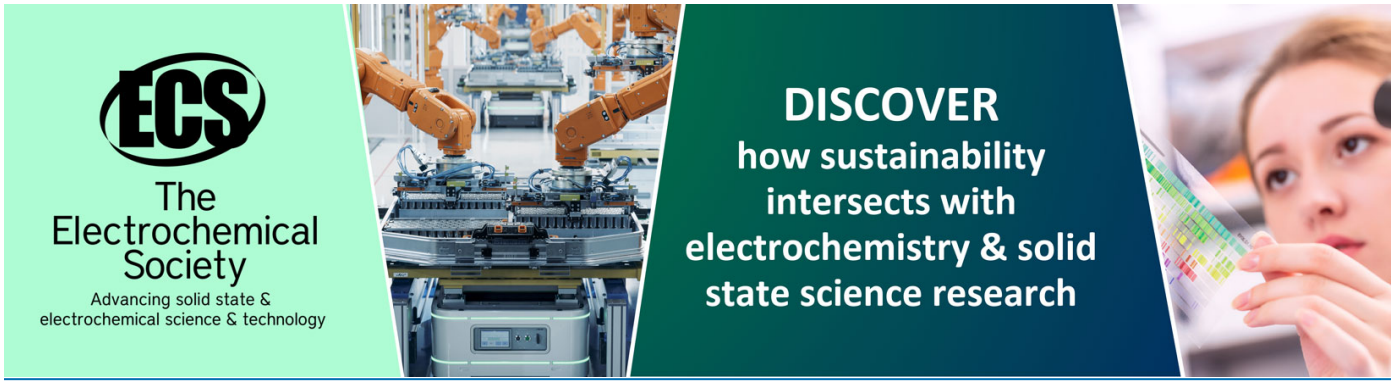
Barriers for Innovation in Road Construction – a Technical Consultant's Perspective



Barriers for Innovation in Road Construction – a Technical Consultant's Perspective

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Abstract. Technical consultants develop visions into buildable designs. Despite having a large impact on a construction project, there is a lack of research into the consultant's potential contribution to innovations. The main measure to stimulate innovation in the construction sector is providing contractor with degrees of freedom through design-build contracting. This contracting form is not new, but there are still problems with the sector productivity. Consultants enter construction projects in the planning stage and set the framework for what the contactors, in the following phase, can build. This paper aims at identifying the consultants' incentives for innovations in road construction. Four barriers for consultants to preserve degrees of freedom in the planning process have been identified: the legislation, strive for concretion, fixed prices payment schemes and monetary bonuses on finishing the road plan obstruct innovation. Removing such barriers can both improve productivity and contribute to a more sustainable construction market.

1. Introduction

Construction industry is often described as having low productivity [1]. Even though these statistics can be questioned due to difficulty of controlling the quality and comparability between countries and sectors, there has been still a strong effort to enhance productivity in the sector.

The main measure for enhancing productivity in the construction industry is giving the contractors degrees of freedom and incentives to innovate [2]. This is often operationalized through design-build (DB) contracting, where the client defines his product in functional terms without detailed designs for building it by contractors. However, the most common way of contracting construction is still the traditional design-bid-build (DBB), where the client designs the product in detail and the contractors build in accordance with the pre-specified design. The argument is that DB support innovation is based on the assumption that contractors are superior to the client in finding new solutions. Although, this assumption is reasonable on a theoretical level, empirical studies comparing DB and DBB are missing. Regardless, whether the client or the contractor is more capable of providing innovations, opportunities to try new things are a prerequisite for both.

Degrees of freedom diminish with the progression of a project, as it is difficult to go back on what was decided. There is a consensus in the construction management literature on getting the contractors involved as early as possible, often in a partner type of relationship with the client (see e.g. [3]). An example of early contractor involvement (ECI) can be seen from [4]. Hence, much of the literature on innovations in the construction industry is focused on contractors [5–7]. This paper focuses on the phase before procurement of contractors and its aim is to identify the technical consultants' incentives for innovations in road construction. The aim of the paper is to detect barriers that prevent consultants'

degrees of freedom in designing roads. Although, the study focuses on Sweden, the results are relevant for all countries with an extensive planning process of infrastructure projects.

The definition of a consultant is wide. This term refers to technical consultants assisting road planning and construction.

The paper starts with a general description of construction market in the following section, focusing on the technical consultant's role. Chapter 3 follows by a description of the Swedish infrastructure market, planning process of a road and Swedish market for consultants. Chapter 3 provides a setting for analyzing the incentives for the Swedish consultants, which is covered by chapter 4 and concluded in chapter 5.

2. Construction market

Construction industry differs from other sectors because its final product is unique, immobile and of high variety [8]. In other words, the road constructed is project based. Secondly, on the contrary to manufacturing, the inputs are brought to the location of the final product and not the other way around. Finally, construction projects are heterogeneous with each product different from the other. These three characteristics define construction industry in contrast with many other industries. One conjecture following this is that mass production might not be suitable. Although it has been tried many times, industrialized construction has not become successful [9, 10].

Another characteristic of the construction industry is the fragmentation of firms. There are a lot of contractors with different skills needed for completing a project [11, 12]. This market structure, building on division of labour, can be contrasted to a potential structure, where all required competences to complete a project lie within one client organization or one company that the client contracts. Theoretically, this is the make-or-buy question researched by Williamson [13]. Williamson analysed whether a firm should produce in-house (make) or use the market (buy). The answer to the make-or-buy question lies in transaction costs. High transaction costs of using the market entail incentives for in-house production and the other way around. The magnitude of the transactions costs can be decided by five dimensions in a certain transaction, namely the specificity of the investment, the frequency of the transaction, the complexity of the transaction, the difficulty of measuring outcome and the connectedness to similar transactions [14]. Appling these dimensions at the construction industry, transaction cost has been defined as ex-ante costs for market research and financing opportunities, conducting a feasibility study, evaluating bids, negotiation and day-to-day pre-contract project management but also by ex-post costs of day-to-day contract administration, administering claims, change orders and dispute resolution [15].

Using a transaction cost approach, Winch [9] tries to answer the question why the construction industry is so fragmented. Based on a theoretical analysis, he provides three potential explanations. The first is that subcontracting instead of in-house production is a way to avoid risk by passing it on and obtain flexibility. Secondly, construction companies try to minimize fixed assets and therefore prefer market to in-house production. However, this hypothesis would be dependent on interest rates and change when capital costs are low. The final explanation refers to clients using design-bid-build contracts and thereby preventing technical consultants from vertically integrating with construction companies. Empirical support for these claims is still missing but the fragmentation of the market is evident.

2.1. Studies on technical consultants in construction

Therefore there is a separation between a client, contractors and consultants in the construction industry. Studies on improving the productivity of the sector have mainly focused on the relationship between a client and a main contractor [5–7]. The lack of research into the role of consultants is surprising, as most studies conclude that consultants are influential for the outcome of the project [16]. This is based on the notion that well-planned project, which is done in the early stages of a project, has a better probability of being successful.

Within the construction management literature, studies on consultants can be divided into four thematic groups. The first category tries to define what constitutes key performance indexes for consultants. Salter and Torbett [17] use interviews and conclude that a broader perspective is needed when looking for good measurements, e.g. by studying leading manufacturing companies. This result is so general, as it has become trivial. Ling [18] and Ng and Chow's [19] national questionnaire studies on the best key performance indexes cannot be generalized.

The second topic of studies [11, 20] tries to find, in a normative way through questionnaires, if local consultants have the capacity needed to perform what is required. This normative question cannot be approached as a method, as the respondents do not have knowledge about the capacity of the firm.

There is a general trend of consolidation consultant services on the market, with larger firms obtaining smaller competitors [21]. Using a questionnaire, Kreitl and Oberndorfer [20, 22] conclude that the main motive for acquisitions is finding new markets, geographically but also in terms of new services. Tang et al. [23] indicate that the most important issues when entering a new geographical market is political, physical and corruption aspects. Bröchner et al. [24] undertook a case study and concluded that face-to-face meetings, e-mail and technical business gatherings are perceived as the most important issues when firms from different countries are joined.

The main bulk of studies regarding consultants look at incentives for achieving client's goals on project level. Kometa et al. [25] and Lam et al. [26] tried to identify what attributes are needed in order to succeed with a project. Eriksson and Kadefors [5] focus on incentives in early stages of a construction project. They define distinction between intrinsic and extrinsic incentives and conclude that there should be a mixture of these. Hojem and Lagesen [27] and Murtagh et al. [28] focus on the incentives for consultant to incorporate environmental perspectives in the design. Both studies are based on interviews but come to different conclusions. While Hojem and Lagesen [27] conclude that legal regulations are the most important incentives, Murtagh et al. [28] perceive that autonomous and self-determined motives are dominating.

The last category of papers is the closest to the issue of the presented paper. However, this study differs both in specific question and a method. While earlier papers studied project goals and environmental issues, this paper focuses on productivity and incentives for innovations. Instead of using cases and interviews, the analysis below builds on documentation from projects completed with interviews. This allows going into details in the institutional setting and in the most important steering documents – the contracts. Contracts are identified as both a potential barrier and an enabler of innovations. However, this project undertakes a method of document studies in order to identify the incentives for the consultants in proving innovations. It focuses on road constructions in Sweden. Prior to going into details, the institutional setting of the Swedish market for road construction has been described.

3. The market for building roads in Sweden

The Swedish Transport Authority (Trafikverket) is responsible for the major roads in Sweden. Urban roads are taken care of by the municipalities and the rest are private roads. All of Trafikverket road construction and maintenance are contracted and procured according to the EU-directive (2014/24/EU). Trafikverket procures construction work (including rail) for about 3.2 billion EURO per year, which represents approximately 1 per cent of GDP.

In an international setting, the Swedish market for road construction stands out in two ways. Just like the construction market in general, the Swedish market for road construction is fragmentized. There is a high degree of separations between consultants, contractors and subcontractors without vertical integration. However, the Swedish road market stands out in being concentrated. Four largest companies dominate almost 60 per cent of the market. This is a high concentration ratio in comparison to the comparable neighbouring countries of Norway and Denmark, see Figure 1.

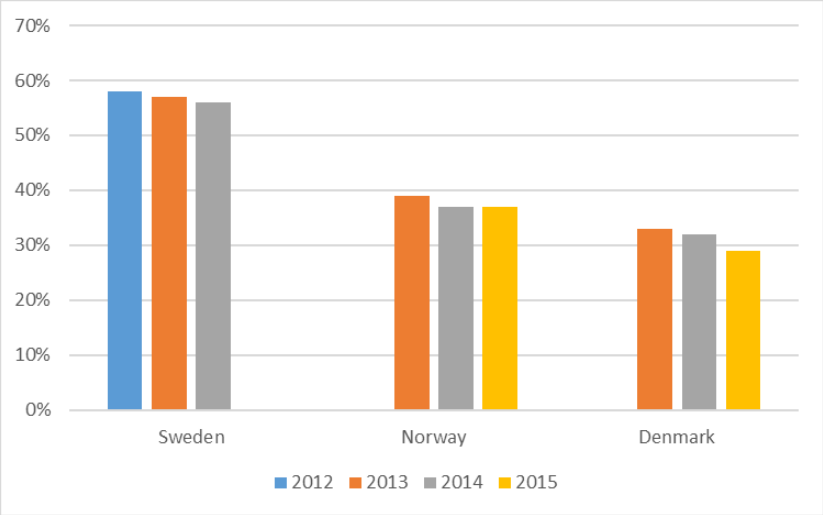

Figure 1. Market share of four largest companies regarding road investments and maintenance in Scandinavian Source: Statistics from Trafikverket (SWE), Vegvesendet (NO) and Vejdirektoratet (DK).

These market shares can also be compared to the asphalt market in California and the USA, where Caltrans is the public client. Between 1999 and 2005, four largest contractors held 45 per cent of the market [12].

The second issue where the Swedish road construction market stands out is the client's belief in design-build contracting as a way to improve productivity. Sweden has had three official government reports since 2000 promoting DB contracting [29–31] and Trafikverket has acted accordingly.

This contracting form can be contrasted to the traditional design-bid-build (DBB) contracting in the construction industry. In a DBB contract, the client is responsible for the design and the contractor builds accordingly. In a DB contract, the client describes the wanted product in functional terms e.g. a highway between town A and B with requirements on friction, roughness (IRI), cracks etc. Then it is up to the contractor to design and build the road. DB contracting shifts the design risk from the client to the contractor. The underlying assumption is that DB contracting will increase productivity, as it gives the contractor degrees of freedom to come up with new solutions. From a consultancy perspective, the difference between those contracting forms is that the consultant designing the road works for the client in a DBB contract and for the contractor in a DB contract.

Trafikverket has since its formation in 2010 pushed for DB contracting. A target was set up, that 50 per cent of all road contracts should use DB in 2018. This target was already met in 2015 [32]. Critic has been put forward that the quantitative target resulted in a relabeling of DBB contracts to DB contracts [33]. However, it is demanding to change traditional ways of doing things in large organisations. Trafikverkets DB contracts have been slowly using more functional descriptions with larger degrees of freedom.

Therefore, the Swedish market for road construction is characterised by a high concentration of contractors and a push for DB contracting. Both these issues have been analysed in order to enhance productivity in Sweden, but less attention has been paid to the consultants' contracting forms and their degrees of freedom to come up with innovations. If given large degrees of freedom in designing the road, depending on the contract with either Trafikverket (DBB) or the contractors (DB), consultants have the opportunity to find innovative ways of building.

Technical consultants can enter the process of a road construction at different stages and take on different kind of roles. They can enter the planning process, the detailed design phase or become a monitoring consultant (i.e. quantity supervisor) in the building stage. Their incentives to promote productivity can be described as dependent on three aspects: stage where they enter the process, entity who they work for (client or contractor) and how the contract is stipulated. In order to shed light on

these aspects, the following two subsections describe the Swedish planning process, the market for road consultants and the contracts used.

3.1. The Swedish infrastructure planning process

In 2013 a new planning process for infrastructure was adopted in Sweden. One key feature of the new process is flexibility [34] which complicates describing the process in a simple and chronological manner. Therefore, the following description in eight steps cannot be seen as a comprehensive but a basic description of all important phases of the planning process.

The planning of a road starts with a (1) financial framework being decided by the parliament. This framework gives the budget for the forthcoming 12 years and is revised at least every fourth year. The next step is for Trafikverket to undertake a (2) strategic choice of measures that analyse the deficiencies and problems within the current system to find alternative solutions [35]. The core of this analysis is the four-step principle (*Source: Trafikverket, 2013*):

> Step 1: Rethink – Measures that can affect the need of transportation and choice of transport mode
> Step 2: Optimise – Measures that make the utilization of existing infrastructure and vehicles more efficient
> Step 3: Improve - Limited amount of reconstruction and improvements
> Step 4: Invest - New constructions and major improvements

The four-step principle is a planning tool that initially tries to improve the current infrastructure with organization changes or policy instruments (step 1-2). If this is not enough, construction is undertaken (step 3 and 4).

Provided that the construction is needed, the next phase of the planning is to estimate the cost and the benefits of the project. Sweden has a long tradition in carrying out cost benefit analysis (CBA) regarding infrastructure investments and this method is robust [36]. However, the analysis does not capture all effects such as labour market expansion and certain environmental issues (although climate issues are included). The CBA and the relevant aspects which are not included in the CBA, are summed up in an (3) overall impact assessment. All projects are ranked in accordance with the overall impact assessment and handed in to the government, which decides on the (4) national transport plan. This plan is a running 12-year plan, where the government selects candidates from the overall impact assessment. The projects chosen by the politicians do not coincide with the ranking of the overall impact assessment in Sweden [37].

After the government decision on preferred projects is made the physical planning starts. This is an (5) integrated process where all stakeholders get consulted, the necessary land is bought, an environmental impact assessment (EIA) is undertaken, and (5b) Trafikverkets plans its own budget. All of these measures are applied in order to improve the (6) road plan. The road plan provides legal conditions for building a road, in accordance with Swedish legislation (Vägförordningen, SFS 2012:707 and Väglagen, SFS 1971:948). Once the road plan acquires legal status, the (7) detailed design of the road starts and finally (8) construction is procured.

This is a simplified version of 8 key steps in the Swedish system for building a road. The time spent between the first to the last step is very different depending on the project characteristics, financial state of the government but also on political aspects of the project. From European perspective, the governmental agency Trafikverket undertakes much of the planning in contrast to other countries where more planning work is done by the ministries. This can be seen as an effect of the relatively large Swedish agencies in relation to the ministries [37].

3.2. The Swedish market for technical consultants

Trafikverket procures all its road construction and maintenance. Although some technical design competence is still in-house, most of the work is also contracted out. The value of Trafikverkets

contracts for technical consultancy in 2016 was 144 million EURO, approximately 21 per cent of the road investments. A general trend on this market globally, as well as in Sweden, is that firms consolidate [21]. This could be an explanation for the decreasing number of bids that Trafikverket receives. The average number of bids for these contracts was 4.4 in 2014 and 3.3 in 2016. In 2014, the market share for the four largest firms was 51 per cent, which rose to 60 per cent in 2016 [38]. This figure can be compared to the market share for the four largest technical consultants regarding roads in Norway which was 50 per cent in 2017 [39].

Outsourcing these services entails that the contract between the client and the contractor is decisive for output. The incentives stipulated in the contract steer the consultant to the final product. There are four types of contracts for technical consultants on the Swedish road market, described as A-D in Figure 2. This Figure also includes eight steps from the planning process.

The first contract is the road plan (A). Here, the consultant assists Trafikverket with getting the road plan accepted. The work includes setting up discussions and negotiations with stakeholders. These stakeholders can be municipalities and adjacent landowners but also local organisations of different kinds. Discussion among stakeholders is to be seen as part of the democratic process of building a road.

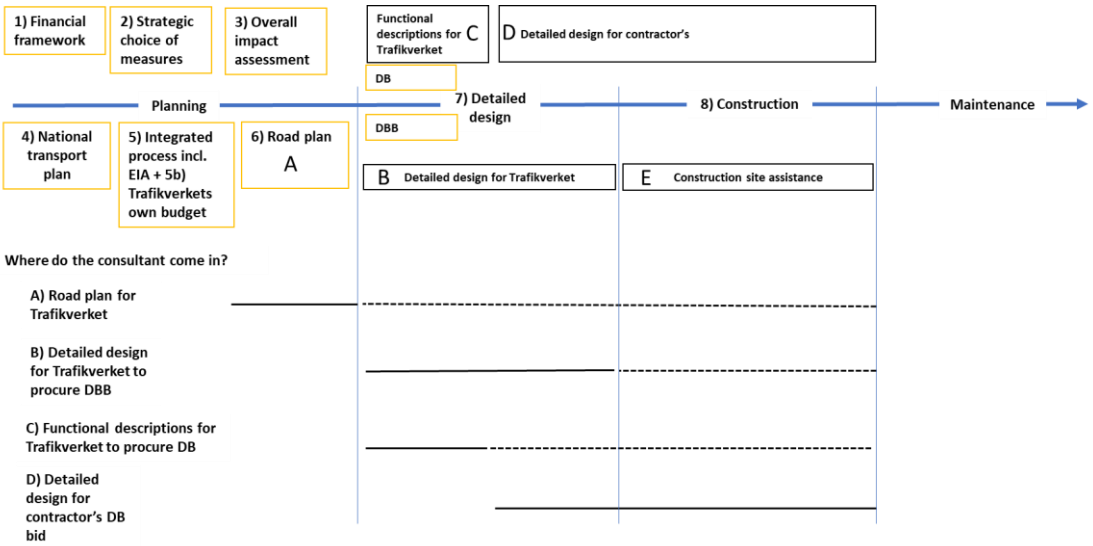

Figure 2. Consultancy contracts for infrastructure in Sweden.

The second type of contract is providing a (B) detailed road design for Trafikverket in a DBB contract. This includes the contractor designing the road in full but also preparing the contracting documents for Trafikverket to procure construction.

The third contract is (C) preparing the contracting documents for Trafikverket to procure a DB contract. This work consists of delivering functional descriptions of the road, from which the contractor develops detailed designs in the next phase.

The last category of contracts is the consultant working for the contractor in a DB contract (D). This work consists of developing a bid for a road project based on the functional descriptions together with the contractor in Trafikverkets contracting document. Choosing to work with the contractor comes with an additional risk, as it is not just up to the consultant, in comparison to A-C, whether the contract is won. The bid developed together with the contractor is competing against other bids.

Trafikverkets consultancy contracts (A-C) can be combined in different versions, indicated by the dotted lines in Figure 2. For example, the road plan (A) is often procured with an option of providing the detailed design of the road in the procurement of a DBB (B) or the less detailed procurement document of the DB contract (C). There are, however, some bias situations to consider among the

contracts. A consultant cannot bid for both C and D. There are also situations where a consultant working for Trafikverket in A, cannot bid on B-D due to information advantage. A relatively new assignment introduced by Trafikverket is for the consultant to assist the client during the construction, both in monitoring aspects and re-designing issues but also to provide a feedback of knowledge for the consultants. This contract is called construction site assistance (E) and, if used, is combined with contracts A, B or C.

In general, there are two payment schemes in construction, fixed price or cost plus [40]. All of the contracts above use payment schemes somewhere in-between these extreme versions. The traditional and still common contracting form is a unit price contract, where consultants set an hourly rate for different types of consultants and get paid by an hour. Trafikverket has gradually promoted since its start more fixed price contracting with consultants. However, there is a mix between different payment schemes in these contracts. However, contract D with the contractor as a client is not regulated by the public procurement regulation. This gives both parties more flexibility in designing the contract, e.g. a long-term contract over several projects can be used.

Figure 2 provides a general description of the Swedish consultancy market from a contracting perspective. In the search for higher productivity, studies on this market are missing. Instead of going into details of the incentives for consultants, studies and policy recommendations often ignore the unique design competence and suggest that contractors should be involved earlier i.e. taking over the consultant's job or using them as subcontractors. The following section does not follow the DB logic of giving the contractors degrees of freedom in order to find innovative solutions, but instead focuses on the incentives for consultants to attain degrees of freedom in the road plan. The road plan is decisive for innovation opportunities as well as new solutions in the next stage i.e. the technical design.

4. Barriers for degrees of freedom in the road plan

Degrees of freedom represent a prerequisite for finding innovative solutions in road construction. This is applicable independent on contracting type. Both DB and DBB contracts could result in new and alternative ways of building road, however the road plan that precedes the detailed design must give such opportunities. Practitioners have indicated that the road plan often decreases the degrees of freedom for what is possible to design. This would affect all parties, the client, the contractors and the consultant's possibilities to come up with innovations.

Based on the institutional setting and contracts in Sweden, four barriers for preserving degrees of freedom in the road plan have been identified.

The first barrier is based on the legislation. Building a road in Sweden is regulated by two laws, Vägförordningen (SFS 2012:707) and Väglagen (SFS 1971:948). Both acts of legislation regulate how a road plan should be undertaken, and explicitly state that intrusion and inconvenience should be kept to a minimum (SFS 2012:707 §2 and SFS 1971:948 §13). These paragraphs constitute the basis for getting the road planned approved and gaining legal force. However, the road plan contract is built on these paragraphs and gives the consultants incentives to minimize intrusion and inconvenience. This means that there are no incentives in the road plan to e.g. make the road area bigger than necessary or prepare designs which are not ordinary. The road plan will incorporate the necessary road area or noise level to complete project, but the legislation does not encourage going beyond the required. It is possible to expand the degrees of freedom in the road plan and thereby allow for unconventional designs in the next step i.e. the detailed design phase (contract B-D in Figure 2), but that requires extra effort as it is not the default level.

The second barrier concerns the importance of concretion. It builds on the hypothesis that it is easier to discuss detailed descriptions and plans than big visions expressed in functional terms. Stakeholders commenting on the road plan are usually not specialised in road construction. For them, it is easier to present detailed plans instead of general visions to react on, discuss and later accept the road plan. In order to get the plan approved, there is an incentive for the consultant to be as specific as possible pushing the road plan closer to the next step which is the detailed design.

Trafikverket promotes fixed price payment in their consultancy contracts. This payment scheme can be seen as the third barrier. Despite initial problems of interpreting which parts to include in the contract, this payment scheme is currently implemented. Fixed price payment has the benefit of putting less risk on the client and provides high-powered incentives to cut costs for the consultant. Some consultants indicate that this payment scheme has entailed initiatives to further develop automated calculation to be more cost efficient. Trafikverket used this payment scheme in contracts A and B. However, when applied to the road plan, it does not give consultants incentives to take measure out of the ordinary. Profit is maximised by cutting cost and still delivering the final product i.e. a legally approved road plan. Initiatives to increase degrees of freedom for the succeeding detailed design often cost more than just delivering a road plan without intrusion and inconvenience. However, the fixed price payment scheme does not provide incentives for endorsing degrees of freedom in the road plan. In contrast, a cost-plus contract reimbursing the hours undertaken, facilitates making such an effort.

The forth barrier is found in one of the analysed contracts, where consultants often get a bonus if getting the road plan approved earlier than estimated. This puts pressure on the consultant to negotiate and discuss the road plan as fast as possible, not leaving room for alternative solutions like expanding the degrees of freedom. Most road plan contracts include a standard monetary penalty for delivering after a pre-specified date. Such contracts give the consultant incentives delivering on time, but a bonus payment on being early is pushing it further which might have effect on delivering degrees of freedom.

These four barriers for preserving degrees of freedom in the road plan have been identified by studying the institutional setting and contracts in detail. A next step would be to address them with data in order to study the magnitude of their importance.

5. Conclusions

There is potential for enhancing productivity in the construction sector. The main measure to achieve innovations is to apply design-build contracting and give the contractor degrees of freedom to develop new solutions. Despite being applied for many years, especially in Sweden, no significant results in innovations can be deduced from this contracting form. These missing results can be explained by a number of reasons. One could be lack of data to compare and do statistical analysis. Another reason could be that the application of DB contracting does not provide real degrees of freedom and does not allow unconventional construction. It has also been put forward that contractors cannot handle the additional risk that comes with DB contracting. These are reasons already discussed in the literature and all of them focus on the relationship between the client and the main contractor. This paper provides a new approach by starting the analysis at an earlier phase and looking at the technical consultants' incentives in the planning process.

The construction market is fragmented and instead of being an in-house resource for a client or a construction company, the competence of technical design is bought on the market. These are the technical consultants that actually transform visions into concrete buildable designs. Despite this impact at the early stages of a construction project, surprisingly little research has been carried out on consultants.

As a setting for analysing the consultant's incentives for innovations, this paper uses the Swedish planning process for infrastructure. However, the results are relevant to all countries with an extensive infrastructure planning process. Having mapped out four types of contracts on the Swedish market for road consulting, the road plan has been identified as a key feature for innovations. The road plan is the last out of six steps of the planning process. It needs to gain legal force before the detailed design of a road starts.

A hypothesis why there is a lack of degrees of freedom for contractors to innovate, results in the fact the DB contracts are bound by the road plan. Based on this premise, four barriers for consultants to preserve degrees of freedom in the road plan have been identified.

The first one is the legislation which stipulates that intrusion and inconvenience should be minimized. This entails that the easiest way of getting the road plan approved is not to expand the degrees of freedom but to diminish them. A second barrier builds on the assumption that it is easier for non-professional stakeholders to understand detailed plans instead of general visions. It is proposed that the probability of getting the road plan approved in discussions with stakeholders can be improved by making the plan as close as possible to a detailed design. The third barrier concerns the payment scheme, where Trafikverket has started to reimburse consultants with a fixed price. This provides the consultant with incentives to minimize cost and restricts doing anything out of the ordinary as expanding the degrees of freedom in the road plan. The last identified barrier concerns bonuses for getting the road plan approved as early as possible. This incentivises promote working as fast as possible and not taking time to think of unconventional solutions.

Nevertheless, there are mechanisms in the institutional setting and the contracts that steer the consultants away from providing as much degrees of freedom as possible in the road plan. This has an effect on the opportunities of innovations and new solutions in the next stage i.e. the technical design. Regardless of whether the client chooses a DB or a DBB contract for the construction, both contracts are in need of degrees of freedom for developing innovative and unconventional solutions.

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