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A Research Agenda for Green Procurement of Infrastructures

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Abstract—Construction and maintenance of road infrastructure is a major source of emissions and energy usage. Procuring green roads, however, is neither commonplace nor trivial to implement. New ways to enhance the green procurement of roads are therefore needed, and can potentially involve life cycle assessment and green labelling methods. Considering the complexity of the pavement industry sector with its many actors and structures, implementing such innovations in the procurement process is surrounded with a series of uncertainties.

The current paper formulates a research agenda for green procurement of roads by looking into potential mechanisms for future procurement. Given the objective of green procurement, the paper is focusing on the question what are the short term and long term effects of potential combinations of life cycle assessment principles and procurement process structures on infrastructure costs, risks, environmental impact and the structure of the road sector. Six different approaches are presented and reviewed for relevant earlier work in the literature.

Based upon the complexities found, the authors discuss the challenges in finding a matching single research method. A solution is proposed for a holistic approach using gaming simulation, since it allows evaluating the procurement of infrastructure as a complex adaptive system.

Keywords—Green Public Procurement; LCA; road infrastructure; complex adaptive system, socio-technical system

I. INTRODUCTION

In the era of sustainability, an important question in the management of infrastructure is how to ensure that roads become ‘green’, since the fuming, bitumen-laden and with heavy construction equipment constructed infrastructure has so far been far from optimised from a life-cycle perspective. Purchasing of larger infrastructure projects nearly always follows a formal procurement process, due to the mostly (semi-) public authority responsible for this.

But how do you order a green road? Besides the challenge of defining the term ‘green’, there are several other major issues when it comes down to green procurement: Should it be green in construction, in use or in maintenance? How could one enforce these? Is it possible to include a life-cycle

perspective during the procurement? What are the system boundaries to be included? How would one ensure the ‘greenness’ from a system’s perspective? And who is taking responsibility for that? Considering the various stakeholders involved, these types of questions are of key importance for sustainable roads. Because of the complex interactions between long term sustainability goals, procurement processes and multiple stakeholder-interests, fundamental insight is needed into their dynamics when moving towards green roads. Feedback cycles within this sector are very long, due to the expected lifetime of transportation infrastructure. This leads to the situation that the actual effects of green road choices may only appear much later.

Therefore, given that the problem has (i) a multi-actor nature, (ii) separation of responsibilities between and within authorities, (iii) a very particular market structure, and (iv) unknown long-term interactions resulting from particular parameter settings, one can characterize green procurement of infrastructure as a complex adaptive system with strong sociotechnical phenomena.

The current paper explores the issues of green procurement of infrastructure, using the upcoming road procurement innovations in Sweden as a case study. By giving a review of the literature on the sub-aspects of this dilemma, the broad overarching research question is sharpened into tangible topics that can be covered in several research projects.

II. RESEARCH OBJECTIVE AND QUESTIONS

Transport infrastructure is an important part of today’s world in both developing and developed countries. It provides many functions for economic growth, living standards, people connectivity and other processes [1], only increasing its volume in time. According to International Energy Agency, the number of passengers and freight travel worldwide is expected to double by 2050 [2]. This would lead to increases in the number and width of roads as well.

Developing new infrastructure and maintaining the existing one produces emissions that may affect air, water and land quality, as well as influence flora and fauna. In order to improve this situation, sustainable development strategies are developed. These are mainly focusing on sustainable processes, effective energy usage, protecting natural resources and creating sustainable communities and a fairer world [3].

Infrastructure development is sustainable, when it tries to satisfy market demands at the lowest possible environmental, social and economic costs, so by more efficient and cleaner ways [4]. Considering the size of current and future infrastructure, making green roads can significantly contribute to sustainability in general.

Green roads require many innovative approaches, and since major buyers of road infrastructure are governments, it is possible to increase 'greenness' of infrastructure with government support [5]. The most effective tool in this process would be using a green public procurement [6].

A. Research Objective

Green procurement might become an effective tool, but given that procurement of infrastructure is a complex adaptive system, there are big challenges to find out how to actually procure. Hence, the research is focused on setting up a system that would allow for testing different ways of combining all system elements together in order to lead to a sustainable system and give guidelines for requirements for procurement. Based on this, the objective can be formulated as:

The research objective is to green the procurement of roads in a holistic, system level perspective.

B. Research Question

In order to reach the objective, the following overarching research question is formulated that focuses on the systemic effects:

What are the short term and long term effects of potential combinations of life-cycle assessment principles and procurement process structures on infrastructure costs, risks, environmental impact and the structure of the road sector?

The question is focusing on the use of Life Cycle Assessment (LCA) as a tool for environmental impact over the entire life cycle of the product or service. It also takes into consideration that procurement and LCA focus on processes with different time scales – while LCA observes the entire process (long term), procurement is mainly based just one step of life cycle (short term).

Infrastructure costs and risks are of major importance for a typical procurement process, while environmental impacts determine the 'greenness' of the procurement. Therefore they can serve as key indicators.

Since combining LCA and procurement touches upon a multi-actor system of different stakeholders, each with their own positions, it gives base for holistic studies. Since the road sector includes few suppliers and few clients compared to other industries, changes are actually feasible and can be designed, but are also difficult to get right as regular market forces are not always in place.

C. Research Sub Questions

Traditionally there is very weak connection between procurement and LCA, if it exists at all. Procurement usually focuses on other properties of roads such as functionality and price, while excluding the environmental aspect. Based on this, the first research sub question is introduced:

SQ1: What are short and long terms effects of traditional procurement on environmental impacts of the road sector?

Some procurement projects include few LCA elements in the process in the form of green building material requirements. There are many certification programs for various materials and equipment. Such approach provides partial connection between procurement and LCA that is easy to realise for both consumer (road authority) and potential bidders. This leads to the next sub question:

SQ2: What are short and long terms effects of green building materials requirements in procurement on infrastructure costs, risks, environmental impact and the structure of the road sector?

Another approach is to measure the 'greenness' of companies based on their business operations and projects that they have done in the past. Companies are assessed, and based on evaluation receive a level of 'green' label. This level is used in procurement as one of the selection criteria or provides access to other benefits. To study the effects of this mechanism, we propose:

SQ3: What are short and long terms effects of corporate sustainability labelling on infrastructure costs, risks, environmental impact and the structure of the road sector?

Participants in the procurement process can be required not only to present their solution but also to perform a life cycle assessment in their bids. Such approach may lead to an increase of sustainable designs at every stage of the process. Such requirement of LCA for bidding leads to another research sub question:

SQ4: What are short and long terms effects of LCA by constructors on infrastructure costs, risks, environmental impact and the structure of the road sector?

The consumer (road authority) can also perform an LCA as part of the tender analysis in a unified way. The bid that is awarded in the tender is calculated using a weighted score, where one of criteria is the LCA result. This mechanism is the subject of one more sub question introduced here:

SQ5: What are short and long terms effects of LCA by the procuring agency on infrastructure costs, risks, environmental impact and the structure of the road sector?

Our last proposed sub question is based upon a mechanism to analyse previous road procurement projects with post-project LCA for developing the best practices in determining both technical and functional requirements, and also making other procurement decisions as type of contract, type of procurement, selection and award criteria etc. From this we obtain:

SQ6: What are short and long terms effects of previous project evaluation using LCA tools on infrastructure costs, risks, environmental impact and the structure of the road sector?

III. LITERATURE REVIEW FOR GREEN PROCUREMENT

Each of the sub questions is explored deeper based on the existing papers in a literature review. Aim of this review is to observe each approach from the view of its environmental aspect. It is done in order to better understand the main concepts as well as the weak and strong sides of each approach.

Sources of information are academic databases mainly within Scopus, Web of Science and Google Scholar, but not limited only to these three. Search is performed looking to specific keywords in article titles and abstracts. Most of the searches included words: road, procurement, construction projects, sustainability, green, environment, LCA, testing, best practice, stakeholders, policy etc. Majority of search queries are limited by the last 10 years in order to avoid out-of-date information. Beside direct search, review of literature references of selected papers is also used, as well as search of other works by authors. Some articles are reviewed using automatic suggestions that some sources provide.

A. SQ1: Traditional Procurement

Formal Procurement guidelines in Europe are defined by the European Commission and are presented as EU directive [7]. The directive considers specifications and contract document development as a start point of procurement, and the signing of the contract as the end point. Nevertheless, in practice, the procurement process usually includes a follow up and can include a warranty period for the road economic life [8]. Still, monitoring of the road and warranty are mostly related to functionality of the road rather than its 'greenness'. And even in cases where environment-related requirements are mentioned in procurement projects, in practice they are not always met or are evaluated as part of the quality assurance control [9].

As a result, traditional procurement can provide a purchase with lower economical cost, but it cannot ensure low environmental cost [10], [11]. And despite the fact that government is focusing on achieving most value for money, it also has a responsibility to protect environmental benefits for tax-payers [12], [13].

Construction industries are primarily focused to fulfil requirements of the projects, so it is the responsibility of the consumer (road authority) to provide an innovative approach. It means that policies can be done through procurement projects with greater emphasis on sustainable value rather than cost [3]. As a result, it will stimulate innovative behaviour for every involved stakeholder [5].

B. SQ2: Green Building Materials Requirements

Green building materials are materials that reduce the amount of resources needed; reduce impact from construction or demolition, and have durable or low-maintenance [14]. Specific tools are used to calculate its environmental effect, so that it is easier to perform procurement in 'greener' way, and often such green labels are sufficient base for considering that requirements for sustainability are achieved [15].

However, green materials cannot complete a full life cycle assessment, because it is highly influenced by the usage of material [16], and the construction, maintenance and

demolition methods. Typically, it is calculated by analysing the process of obtaining the material but not the effects that transportation, usage, maintenance and demolishing cause. Main reason for this is logical, since the history of green labelling is geared towards a label for the material in general rather than for specific application or even project [17].

Another problem with green materials is that companies can mislead consumers by highlighting a single positive product feature while ignoring the negative ones [18]. Often it is done intentionally in attempt to fulfil requirements and maximize the profit, as depicted in Figure 1.

Fig. 1. Stakeholders in road infrastructure

At the same time it is hard for a road authority to define proper requirements for green building materials because there are several certificates from different organisations [19]. Also certificates can be based on different type of 'green' aspect: water pollution, air or land pollution, hazard to animals etc.

C. SQ3: Corporate Sustainability Labelling

A labelling mechanism with third party certification can be a procurement tool that rates companies according to their 'greenness'. The evaluation can be done based on previous work of specific company and on technologies and equipment that are being used. This method allows determining a specific level of awareness of environment within organisation and recommend future development strategies to improve the situation and hence to raise ones level [3].

The level itself is not related to specific procurement project, but rather it can be used as a participation criterion (road authority to specify that only constructors starting from the specific level of 'greenness' may participate in bidding). Also it can be used as an evaluation criterion by giving priority to more sustainable constructors.

The motivation for reaching higher 'green' levels must come from pressure from public clients (road authorities) who push for improved road services and stricter regulations in procurement specifications. Thus competitors will be motivated to improve their environmental impacts and implement process innovations designed to improve productivity and quality [13], [20].

Level assessment has to be controlled by some institution or groups of institutions [21]. This is usually not available in all

countries in the exact identical way. The mechanism may make the procurement process less equal to all bidders because for a new or small company it will be harder to compete with bigger companies with high level of sustainability.

D. SQ4: Life Cycle Assessment by Constructors

An LCA for a specific project can be performed by bidders as a part of the tender. This process must include the entire life cycle so that it can provide results that realistically represent the project.

It is the constructor's task to make sure that every phase of the procurement is as sustainable as possible; and awarding of the tender will evaluate only the final LCA result [22].

There are several readily available tools for LCA analysis that can be used for calculation [23]. However, this also creates a problem, because different tools can provide different results and lead to mischarging the best tender. It makes the process less transparent due to the complexity of testing validity of the LCA calculations for each case.

Beside these constraints, this approach is useful when for design and maintenance contracts. In comparable cases, 'greener' design might have 'less green' maintenance and vice versa [24].

E. SQ5: Life Cycle Assessment by Procuring Agency

Evaluation of the project can be done not only by contractors as part of their bid, but also by the consumer (road authority) as part of an evaluation. This approach works when the number of bidders is not very large, and hence is it appropriate for procurement of infrastructure, where average number of successful bids is less than 3 for a procurement project [25] in Sweden.

Fig. 2. Number of procurement projects based on number of successful bids [25]

Such evaluation can be done by using the same tool for each bid and providing fair and transparent evaluation of offered alternatives. If a transport authority already uses some specific LCA tool on a daily basis, the same tool can be used testing the bids. Such approach will exclude the need to learn and obtain extra tooling, and will provide more ground for mutual process integration.

The approach also allows combining different projects, if the procurement procedure is aiming only for part of life cycle, for example designing, construction or maintenance [26]. If

procurement happens in parallel – combination of different tenders might bring even better solutions.

Another benefit of using LCA by road authority is access to a bigger data set than a private company might have. This also includes access to policies, even on the development stage, when documents are not available to general public, but need to be considered in decision making. This implies that this approach makes it possible to evaluate some different scenarios considering future prospective [27]. This is important for risk analysis, and in cases, when some major changes are predicted in the period of economic life of the road.

Such approach can be complicated when tenders do not provide or misrepresent some of the data for calculation. It limits opportunities for innovation from constructors because their solution might not fully match to the tool used for evaluation and so leads to less favourable results.

F. SQ6: LCA of Finished Projects

Post-analysis of finished projects considering their procurement process and level of 'greenness' can provide information on correlations of these technical and managerial parameters. Based on this information, decision support tools could be developed to predict LCA effects on for requirements on every stage of the procurement [28]. This technique makes enables to influence the procurement process itself in way that it supports 'green' infrastructure.

Data for such an approach is historical data of completed projects. This data should be available, however it could be difficult to obtain because it is not typical data for analysis patterns. Required data are coming from researching the procurement project (the way project was procured), studying the construction documentation (the way project was realized), and observing conditions of the project (the way project was functioned).

These data allow for developing the decision support system using data mining approaches in order to predict LCA outcomes on early stages of procurement. This information is later related to all steps of procuring process, considering both technical decisions and management decisions.

It allows predicting environmental effects while being still on project developing stage [28]. This gives more opportunities to decrease total environmental costs and make a project more effective from the start without a need to wait for the entire procurement process to finish.

IV. DISCUSSION

It is essential to note the difference between Green procurement and Sustainable procurement. Green procurement involves the elements related solely to the environmental impact, while Sustainable procurement involves economic, social, and environmental parameters and demands a more complex approach to the procurement realisation [20].

Most research in the field of road procurement use words 'green' and sustainable as synonyms. And such emphasis on green procurement typically happens because it is one domain where objectives are not in conflict with one another. However in sustainable procurement often objectives can contradict one

another. For example, a new highway might be an economically wise decision, but may not be the best solution from a social or environmental view. So this aspect of sustainable procurement makes procurement of the roads even more complex as a system, introducing elements of system dynamics, where one decision can be good and bad in the same time based on different parameters.

With this comes a problem of determining what parameters are important and how important they are. Typically there is no standard answer on the weights of sustainable procurement parameters and thus making decision for suitability very hard, and so most of projects evaluate procurement of the road just from one aspect of sustainability.

Different solutions can be even based on different views on sustainability. One worldview that sees economic and social levels as part of environmental level (figure 3a). Other worldview sees sustainability only as part where all three levels intersects (figure 3b).

Fig. 3. Sustainability a) as universal set [29] and b) as intersection [30]

Another open issue is a connecting different sustainability approaches to different phases of road life. It means that even best solutions on sustainable development for road construction most likely will be different for road operation.

Even different stages of the same phase might require different solutions. For example, maintenance of road structure and maintenance of road signs and lighting cannot be fully described with one approach despite that both are maintenance processes.

A unified approach does simplify the process and might be justified or even recommended as a tool that oversees a complex system holistically. On the other hand such simplification might lead to exclusion of some elements that are of vital influence.

Another key issue is the distribution of responsibility among stakeholders concerning different aspects of sustainability and different phases of the road life cycle. Currently, road authorities have most obligations in the process, with significantly less accountability from the contactors or from the government. Feedback from indirect decisions is often neglected by all parties, and thus full sustainable impact is not achieved.

Since feedback cycles within the road sector are very long, due to the expected lifetime of transportation infrastructure, responsible institutions may no longer exist or are highly

modified by the time when responsibility is required. The procedure of enforcing the consequences for the actions is unclear in these cases, and so it is not effective and can be highly expensive.

It is worth remembering when applying LCA or any other tool for road procurement that the environmental impact of traffic should not be included because traffic is not what is being procured. Otherwise it might lead to a case where no considerable improvements will be made in environmental sustainability of road infrastructure itself.

V. POTENTIAL RESEARCH METHODS

Typically, research approaches are meant for subsystems of a complex adaptive system. There are methods to evaluate different pillars of sustainability such as LCA for environmental impact, studies of incentives and cultural analysis for social aspect studies, and cost-benefit analysis for the economical level. Modelling and simulation are often used for multi-actor perspectives on the problem. Case studies, statistical analysis and survey research are methods for policies and responsibilities analysis.

Road procurement has both complex adaptive system characteristics and socio-technical system ones. It has elements of social systems such as individual stakeholders, communications, behaviour patterns, and personal values. In the same time procurement also is described by technical system elements – tasks, technologies, equipment, materials. Thus research methods for this problem should be methods for studying socio-technical systems that can capture emergent effects that are dominant in complex adaptive systems.

Typically, socio-technical systems are observed using experiments, case studies, interviews and focus groups, fieldwork and simulation [31]. At the same time, some of these methods are not suitable for evaluating possible consequences of future changes (without implementing solutions beforehand).

Therefore, a potential research method is system dynamics. It is used for dynamic problems like complex social, economic or ecological systems that can include interdependencies, and mutual interactions, including feedback loops [32]. It could use the concepts from green road procurement and decisions of stakeholders as input data and simulates system behaviour and consequences as a result.

A second suitable method would be the use of agent-based simulation [33], where simulation is viewed upon not from dynamic aspect, but rather from individual agent (stakeholder) actions and interactions with other agents. This method would highlight the emergent behaviour, and allows for high repetition of the simulation experiment.

A third research method could be the use of game theory [34]. It allows several players with different choices of behaviour. Game theory allows different objectives for different players while allowing consequences of decisions of one player influencing other players and their choices. This method works based on set of rules that are applied to all players. Game theory typically formalizes game by sequence of steps with value of each node for each of players. Thus it is

more a method to build a model that test a socio-technical system.

The last research method considered for this research is gaming simulation [35]. It differs from the methods above because this is participating approach that allows players to act naturally and to interpret their actions and decisions in holistic perspective. Gaming simulation is also able to help to generate new knowledge by observing behaviour and strategies of the players. Jac Geurts in his work [36] states that simulation games “are safe environments to test strategies in advance, and can help decision-makers to create several possible futures. The players build the future conditions of the system step by step by moving from the current reality to a new vision.”

Thus we see the use of gaming simulation as an appropriate holistic approach for road procurement [37]. It allows evaluating the procurement of infrastructure from different sustainability aspects, it is meant for multiple actors (or players), and it includes policy analysis based on both qualitative and quantitative data from game sessions.

VI. CONCLUSIONS

Green Public Procurement or using green indicators as life cycle assessment in procurement process is an open problem. Reviews of sub-questions and literature studies show that economic aspect, institutions, and technical aspects are essential elements that need to be considered.

If we speak only about ‘green’ procurement, then we will always miss the important system level consequences on market structure, infrastructure costs, risk management, environmental impact and on the structure of the road sector.

Therefore it is crucial that we are going to assess each of the six ways of green procurement identified in the sub-questions in detail and in a holistic fashion. The research methods required to do so involve both the analytical approach and design tools that include the multi-actor perspective of the problem. So a design of (economic) incentives structures shall be accompanied by the rules, institution, and processes that make them effective.

This will be our research agenda for forth coming years.

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