Designing a business model to reduce CO_2 emissions from construction machinery: Aligning business and environmental objectives

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ABSTRACT

The literature on sustainable business models suggests a large potential for radical environmental benefits in many industries based upon current technological opportunities. However, there is a lack of empirical knowledge on how to design, implement and spread such business models in complex value chains. Based on a qualitative exploratory study, a concept for sustainable business models to reduce carbon emission when using construction machinery has been developed and measures needed to implement and design such a model within the construction industry is identified. The study is based upon interviews, study visits and a workshop, with participants representing all important actors in the value-chain. In conclusion, business and environmental objectives can be aligned through a result-oriented business model, supported by life-cycle data, contractual incentives, standardised emission measures and driver visualization. The concept is generalisable to the greening of value chains beyond carbon reduction and also to other complex business to business value-chains.

KEYWORDS: Business model, Carbon dioxide, Construction supply chain, Emissions reduction.

INTRODUCTION

Most business partners can use international agreements on greenhouse gas reductions as an opportunity to increase revenues through designing new kinds of sustainable business models, or sustainable product-service systems. However, to reach both business and environmental objectives these models or systems need to be explicitly and carefully designed (Boons *et al.*, 2013; Heiskanen & Jalas 2003; Lindahl *et al.*, 2014; Tukker 2004). Moreover, their successful implementation and diffusion depends on how they are supported by explicit innovation efforts to change the 'industry regime' in which they are embedded (Ceschin 2013). The application of, sustainable business models to more complex value-chains, involving business to business relations, is evolving much slower compared to business to consumer value chains, with a few notable exceptions such as jet engines or trains (Davies 2004; Smith 2013).

Based on a literature review and a pilot study of current practices in the building industry in Sweden, a concept of a sustainable business model for the sale, procurement, maintenance and use of construction equipment that aims to reach both business and environmental goals is suggested. Construction equipment use is part of a complex value-chain with generalisability for other industries in terms of how life-cycle analysis, public procurement, standardization and innovation research can support the design and diffusion of green business models.

The next section summarizes what the relevant literature suggests for the development of a sustainable and profitable business model. The methods section provides information about our data and means of analysis. In the following sections analyses of the various transactions in the value chain to identify current practice is made, the potential contributions each partner can make to the design and effective implementation of such a concept are outlined as well as what they need in terms of knowledge, data and tools. The concluding section addresses generalizability and the need for further research.

FRAMEWORK: SUSTAINABLE BUSINESS MODELS AND LIFE-CYCLE DATA

Construction equipment is used as part of a construction process which is most often very complex, both technical and organisational, often involving many different partners in a long value-chain: regulator, client, building contractor, construction entrepreneurs, equipment providers and equipment manufacturers.

A sustainable business model concept needs to support different ways to reduce emissions, in terms of reducing carbon footprint, such as changing fuel, using fuel-efficient machinery, optimising the use of existing machinery or the whole work process. It needs to be supported by all the relevant actors through their mutual transactions as well as through their internal processes. Thus, it needs to encompass how equipment providers can best design organizational incentives that support reduction of CO_2-emissions as well as provide economic viability in different situations. The concept also needs to encompass technical data and tools that clients, contractors, entrepreneurs and drivers can use for reducing CO2 when procuring and using the equipment. It needs to address how to implement and diffuse such models.

Reducing Carbon-Footprint through Result-Oriented Business Models

Sustainable business models could be a salient means to achieve a sustainable economy (Schulte, 2013). Business models' structure how a company organizes internal and external relations to create value (Ng *et al.*, 2013). This means that a business model structures and is structured by both product technology and by buyer-supplier transactions as well as various regulations.

The conventional story suggests that the providers' business motives for sustainable business models stems from changes in customer demands that pushes manufacturers into long-term, cooperative agreements with costumers, designing various service offers that provides a higher return on investment (Davies, 2004). In addition, there are also often pull factors. Drawing from a case study of the Rolls-Royce jet engine Power-by-the Hour concept, Smith (2013) suggested that more durable frames made the engines last much longer, pulled Rolls-Royce to design a business model where revenues could increasingly be found through repair and maintenance.

However, new kinds of business models do not necessarily provide radical environmental benefits. They are often conceived of in terms of sustainable product-service systems (PSS) and the design issue can therefore be conceived of as "to identify situations where both the business drives and the sustainability incentives for PSS are mutually reinforcing" (Tukker

2004: 247). Both the business and the environmental objectives have various rationales and effects.

The environmental effects are (only) materialized if business models realise technical potentials for recycling, remanufacturing, reuse, maintenance and holistic planning and operation (Lindahl *et al.*, 2014). These effects could be characterised through dividing PSS into three categories (Reim *et al*. 2014; Tukker 2004):

a) Product-oriented such as product-related and advice and consultancy.
b) Use-oriented e.g. product-lease, product-renting/sharing and product pooling.
c) Result-oriented e.g. activity management, pay-per-service unit and functional result.

Substantial positive environmental benefits, especially for complex value-chains, can only be expected when business models are designed so that both user and provider have incentives to increase the life-time of the existing stock through careful and optimal use as well as design. This is, is best achieved through result-oriented business models which are able to overcome the risk for split incentives (Sundin *et al.* 2009; Tukker 2004).

For example, the use of Rolls-Royce jet engines is charged according to wear as well as time. In a case study comparing one manufacturer's two jet engine after-sales maintenance support programme for the same products, the performance-based contracts showed 25-40 percent higher reliability than the time and material contracts (Guajardo *et al.*, 2012). This finding is consistent with the prediction that the latter kind of programme offers more frequent scheduled maintenance as well as incentives to provide better care. Contract theory to design appropriate incentives for each partner in the value-chain seem to be a useful approach (see Bolton & Dewatripont, 2005).

Implementing and Diffusing Sustainable Business Models

An effective implementation of these PSSs requires specific characteristics or "tactics" (Reim *et al.*, 2014). For result-oriented PSSs these tactics include: low formalization of contracts, freedom on means for provision of results, agreement focusing on results, frequent interaction, comprehensive data collection, increased innovation, much personal communication, high flexibility, high degree of customization, long-term relationships between partners and few customer relationships (Romero & Molina,, 2014) based on high levels of mutual trust and cooperation (Ng *et al.*, 2013). Similarly, Moklesian and Holmén (2012) argue that radical changes in environmental impact from the construction industry are due to changes in value configuration, cost structure, partner networks and capability.

Moreover, an effective implementation of new PSSs also requires institutional reform of the current 'industrial regime' (Ceschin, 2013). There is a need for changes among all actors in the value chain as well as governmental agencies, environmental NGOs and research organisations. All these actors can contribute to effective design and implementation of sustainable business models through interconnected networks that help to transform the way construction equipment is purchased and used in terms of: customers' perceptions and routines; suppliers' organizational structures and routines as well as; regulative framework.

For suppliers, important barriers to implementation and diffusion of PSSs include e.g. the difficulty to quantify savings arising in economic and environmental terms (Ceschin, 2013).

For customers, important barriers include the cultural shift necessary to value an ownerless way of having a satisfaction fulfilled or the lack of knowledge about life-cycle costs.

For suppliers, performance-based business models also entails new kinds of business risks when e.g. manufacturers or providers own the machines and cannot be sure how much to charge customers to cover their costs, especially when the market fluctuates (Gruneberg *et al.*, 2007; Kleeman & Essig 2013; Selviaridis & Norrman 2014).

Moreover, regulators often do not reward companies' environmental innovation, for example, they do not reward them for internalizing external costs. External costs are the costs for environmental impacts from business operations that are not part of business calculations. If building contractors pay the full price for climate impacts, they need to be able to pass them on to or share them with clients.

An effective implementation of a PSS requires setting up collaborative schemes along the whole value-chain that enables new ways to make business. This can be achieved e.g. through communication materials that speak to all parties (Krucken & Meroni, 2006). In this case, collaboration can be achieved through trustworthy and easy to use life-cycle data, contractual incentives, standardized emission measures and work achieved as well as driver visualization.

Designing a Result-Oriented Business Model with Life-cycle Data

To make it sustainable both economic and environmentally, the users of result-oriented business model need scientific data for the whole life-cycle of the machinery, including both costs and performance and including external costs.

Life-cycle cost calculation need to reflect the different options for reducing CO_2 emissions. For example, changing the fuel from diesel to a fuel based on renewable raw materials can be associated with significant environmental impact and energy resource use during manufacturing. The calculation of the performance must include many important features, such as expected lifetime, maintenance requirements, operational characteristics, production costs of the equipment, waste management of the equipment etc. Moreover, a sustainable business model needs to internalize external costs from the environmental impact of the use of equipment machinery. It is only through research-based life-cycle data that external costs can be calculated.

A recent study of buyers and sellers for intravenous catheters show the need for easy to use data which is also driving environmental performance (Stripple, 2013). The buyers and sellers cannot be expected to make environmental decisions based upon their own expertise or on reading the scientific literature. The buyers and sellers of construction equipment need easy to use life-cycle data to compare different equipment for the same kind of work, containing relevant externalities as well as standardized and accepted measures of work. Development and use of e.g. EPDs (Environmental Product Declarations, environdec.com) is appropriate. EPDs standardize LCA calculations for a given product in order to achieve a relevant comparison of the products, based upon ISO standards. An example for infrastructure work is provided in Acciona Infraestructuras (2013).

Measuring and Visualising Emissions and Work in Real Situations

Buyers and suppliers need visualization of data concerning emissions and work achieved so that they can compare different machinery. Drivers also need visualization so that they can relate their driving behaviour to the outcome. Visualization should preferably also be linked to driver support and learning systems. The data supplied should be made available in a standardized format so that different users can make use of software systems that are decoupled from specific machinery brands. Visualization needs to support reduction of CO_2 in different ways.

ISO standards are very valuable for promoting global requirements and to establish acceptance criteria and test methods for the introduction of new technology or processes. Standardization of emissions compared to the work achieved may make use of ISO 8178, a standard for exhaust emission measurement from a number of non-road engine applications. The standard is actually a collection of many steady-state test cycles designed for different classes of engines and equipment. Each of these cycles represents a sequence of several steady-state modes with different weighting factors.

However, standardising the measurement of CO_2 emissions could prove problematic for construction equipment. Any program for CO_2 reduction has to include all the elements of operation – the type of equipment selected, the operation of that equipment, the efficiency of the equipment and alternative fuel sources – in order to optimize and maximize the impact on CO_2 reduction. Systems used in the automotive sector may not be suitable or practical for use in the construction market. Standardization needs to take into account the great variety in use (excavating, loading, transportation), the variety of material being processed (sand, earth, stone etc.), the required quality or precision as well the overall degree of coordination within the workplace (Yoshida & Hirashata, 2003).

METHODS

Literature review suggests that a sustainable business model requires support from trustworthy and easy to use life-cycle data, contractual incentives, standardised emission measures and work achieved as well as driver visualization. To find out how the business model needs to be designed and supported, the study used an exploratory, qualitative case study approach.

The study is exploratory (Stebbins, 2001), because it aims to identify hitherto unknown parameters (challenges and opportunities to CO_2 reduction), before examining their relative impact. Qualitative studies are ideal for addressing "how" questions, from the perspective of those studied and for examining and articulating processes (Pratt 2009). Case studies are particularly well suited for identifying relations and processes in context and for developing theory for similar contexts (Welch *et al*., 2009). Thus, studying the whole value chain makes it possible to map the whole life-cycle for the economic and environmental impact from construction machinery, thus enabling to identify opportunities and challenges to design and support sustainable business models in context.

Moreover, the case was narrowed down to an extreme case (Yin, 1997) in three respects, addressing assumed impact but also assumed implementation difficulties. Firstly, civil engineering, the section of the construction industry which offers the largest potential for CO_2-reduction from construction equipment, compared to housing construction where the largest potential lies in reducing climate impact through the choice of building materials. Secondly, the study focused on the major public clients that have CO_2 reduction assignments, large budgets, specialized staff and tools for climate calculations, such as the Swedish Transport Administration (Trafikverket) and the major Swedish cities (Stockholm, Göteborg, Malmö) as they are best equipped with resources to change procurement practices. Thirdly, it focused on larger and more complex machinery that require more skilled drivers and more advanced technical support, as these are currently often not hired alone, instead drivers are hired with accompanying machines. Identifying opportunities for a result-oriented business model in this segment is salient to achieve significant CO_2 reduction.

After an initial mapping of the value chain through initiated colleagues, reports and guidelines, key people within different partners were identified and interviewed separately as a means to map the current state, understand challenges and opportunities across the chain and suggest how a sustainable business model can be designed, implemented and how the potentials could be realized (Taylor, 2005). Finally, interviewees and other key informants were invited to a workshop to discuss and refine preliminary findings. Workshops are a particularly useful technique to achieve dialogue and mutual learning (Ørngreen & Levinsen, 2017).

People in the following organisations and roles were interviewed and/or participated in the workshop:

1. Regulator: Experts at the Swedish Competition Agency (they are now at the National Agency for Public Procurement), charged with oversight as well as knowledge support for public procurement.

2. Clients: Technical experts and procurers at Swedish Transport Administration (STA) and a big city.

3. Building contractors: Environmental coordinators and buyers of construction work from the three major building contractors.

4. Construction entrepreneurs: A driver and the CEO for their interest group.

5. Construction equipment providers/manufacturers: Technical and environmental experts from two of the major providers an eco-driver trainer, sales and technical experts at one of the providers as well as the CEO for a construction equipment rental agency.

A visit to an engineering worksite was made where the client (the city), the building contractor and a driver were interviewed. A workshop was organized which most of the interviewees attended with a number of other experts (see list of informants in Table 1). A number of generic interview questions were used for both the interviews and the workshop, while also adapting them to specific interviewees when needed. The workshop provided a precious opportunity for feedback on other preliminary findings from the interviews, the field visit and document analysis as well as a precious opportunity for interaction among the different partners.

Data collection and analysis were structured according to three research questions, based upon salient findings from the literature review:

1. What do business partners do today to reduce CO_2-emissions? What shapes their practice and how does it impact on the possibilities for a result-oriented business model that is both profitable and reduces emissions for the use of construction machinery?
2. How can they contribute to design such a business model? For example, what resources are there that could be put to use?
3. What additional knowledge, data and tools (including procurement demands and contractual terms) would they need to that end?

Moreover, because the literature review suggested that the relations between the partners in the value chain are salient both to design a sustainable business model and to realise its potential and because of the limited resources for the study, it was decided to focus on the challenges and opportunities stemming from these relations, and less on the internal processes and structures within the partners. Therefore, the analysis was structured in terms of the different transactions between the partners as these provide the context that enables the design and implementation for sustainable business models:

1. Building contractors vs Construction entrepreneurs: This is the locus for the result-oriented business model.
2. Public clients vs Building contractors: The building contract regulates business and environmental directives and incentives.
3. Construction entrepreneurs vs Providers. The manufacturers' role is addressed in relation to the providers.
4. Regulator vs Public clients: Public procurement regulations structure what is possible but the regulator also provides expert support.

Table 1. Overview of Key Informants' Roles

Code	Organisation	Function	Geographic scope	Interview date	Workshop Apr 8, 2015
R1	Association for construction entrepreneurs	CEO	Sweden	Jan 26, 2015	Yes
R2	Construction equipment provider	Eco-driving instructor	Sweden (Europe)	No interview	Yes
R3	Construction entrepreneur	Buyer of construction work	Sweden	No interview	Yes
R4a	Public client	Procurer construction work	Large City, Sweden	Mar 20, 2015	No
R4b	Public client	Procurer construction work	Large City, Sweden	Mar 20, 2015	No
R5	Regulator	Procurement expert Agency	Sweden	Feb 06, 2015	Yes
R6	Construction entrepreneur	Providing climate data	Sweden	Feb 17, 2015	No
R7	Public client	Functional procurement expert	Sweden	Dec 11, 2014	No
R8	Construction entrepreneur	Environmental coordinator	Sweden	Feb 14, 2015	Yes

Figure 1 gives an overall view of the organisations, roles and transactions. There are other factors that influence the life-cycle of the impact from construction machinery. For example, the STA, the Energy Agency as well as the Swedish Environmental Protection Agency regulate the use of construction machinery in other respects than through procurement and the Swedish Competition Agency regulates the entrepreneurs directly. However, these transactions were excluded from our study.

Moreover, the inter-organisational transactions between the partners is only the first step in mapping the factors (tools, data, knowledge and incentives) that structure and inform how construction equipment is designed, sold, procured, used and maintained. There is also a need to uncover the internal relations within the partners.

The data from interviews and from the workshop was coded both in respect to research questions and in terms of transactions, as a kind of qualitative content analysis (Krippendorf, 2004). Out of this matrix, a number of key issues arouse, in the article summarized in three themes: current practices and structures; possibilities to enhance a result-oriented business model and; the need for knowledge data and tools to support its implementation and spread.

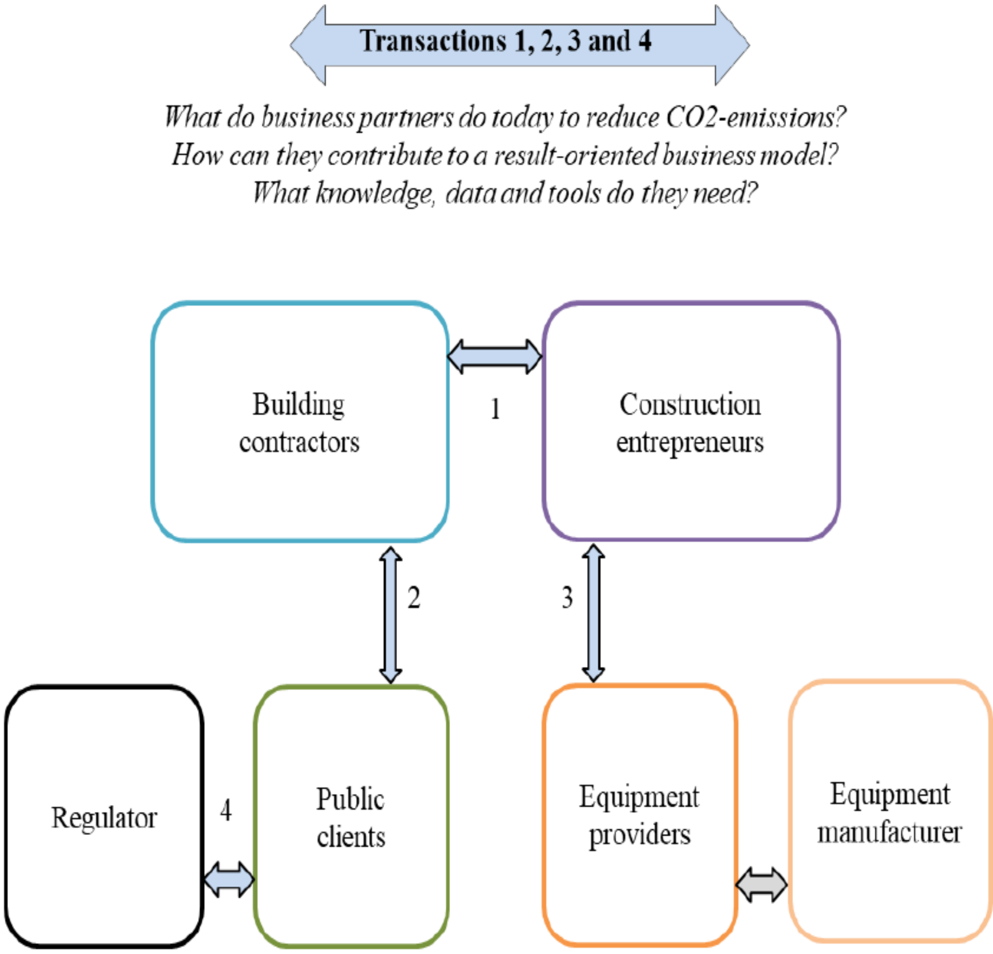

Figure 1 Partners in the Value Chain, Transactions and Research Questions

FINDINGS

Building Contractors (BC) vs Construction Entrepreneurs (CE)

Current Practices and structures

Most construction work in Sweden is currently procured from small construction entrepreneurs (CE), although often coordinated regionally. Many CEs are small businesses, often with one or a few owners or employees, that is, micro-businesses such as "Pelles Gräv". The building contractors (BC) often hire them on an experience-base: they hire CEs with drivers that they experience as cooperative, flexible and offer a competitive price. Thus, BCs hire drivers with accompanying machines, rather than machines with drivers. The competitive situation means that the price is very low and hardly covers life-cycle costs for the owners. They work many hours per week, spending their free time on maintenance. This means that machines and drivers need to be versatile to be able to perform various tasks, some of them not optimal from an environmental perspective if the machines are too small or too big.

CEs are often hired per hour or per work effort but never including externalities, and fuel is often offered on the worksite from a common tank. CEs are also often contracted for a fixed amount, related to an agreed task. Sometimes, extra work due to unexpected circumstances is paid for by the hour. The remuneration is usually not coupled to incentives to work more efficient or to actual measurements: it is the hope for future work offers that provides an incentive to do a good job.

Possibilities to enhance result-oriented business model

The various means for reduced emissions are currently, at best, add-ons. Separately, they only offer marginal contributions. The CEO for the CEs argue that the difference in efficiency is low between the best machines for the same size from different manufacturers (four percent) while the difference between drivers is up to 40 percent for the same amount of work (R1). Similarly, the Swedish Transport Administration (2012) suggests that through upgrading the existing fleet the energy consumption will be lowered with between eight and twelve percent, while more effective use through various means (such as better planning and coordination, changed fuel and eco-driving) will lower it with 14-35 percent. The latter figures include an estimated implementation level of less than 100 percent, thus they do not represent the full technical potential. All of these figures are subject to several uncertainties.

A result-oriented business model with best business and environmental impact requires an integrated solutions package with restructured business relations (Davies 2004). It is difficult for the CEs to add substantial competitiveness as well as reduced CO_2-emissions only through increased product efficiency. It is logical that BCs hire drivers with accompanying machines rather than the opposite. The various means for reducing CO_2-emissions need to be integrated with each other.

To this end, CEs could offer a package including the right machine for the right job in the right moment with a trained, specialist driver, supported by technical support for guiding, learning from and evaluating their work as well as with incentives to work effectively to reduce emissions. They could offer a contract for a specific work to be done, rather than per hour. That would produce incentives for both CCEs and BC to effectively reduce emissions through various means. It would produce opportunities for CCEs with proficient drivers to increase their market share, to invest in eco-driving training; it would produce incentives to use available data for more efficient driving.

Need for knowledge, data and tools

To implement this integrated package there is a need for BCs to be able to compare different machines with regard to their competitiveness in economic and environmental terms, taken as a package. The climate impact also needs to be quantified in economic terms so that it can be entered into business calculations between BCs and CEs, thus internalizing external costs. The internalization will favour more efficient and durable machines and more efficient use of them. Calculations from STA show that the external climate costs from the use of construction equipment are 25 percent of internal costs (Swedish Transport Administration 2014a).

To this end, there is a need to measure work and emissions or fuel consumption in real work and to provide life-cycle data in forms that are useful for buyers at BCs and sellers at CEs. Current calculation programs available at the BCs could be used to this end. Moreover, it would produce incentives for manufacturers and providers to standardize working procedures and provide data that could be used for comparing packages between different providers. There is a need for feedback from the use of the machines to drivers so that they can learn to improve their work.

The calculations provide the data necessary for renewed contract models that provide the necessary incentives for CEs to engage in measures used to reduce emissions for several reasons. If clients pay for (at least part of the) external costs in their contracts with BCs, the efforts that CEs provide to reduce emissions need to be allocated to them through their contracts with BCs. Moreover, when experimenting with new forms for CO_2 reduction and for contracting, there needs to be a higher marginal in the contracts that may cover investments, learning and documentation from pilot projects as well as business risks.

Public Clients (PC) vs Building Contractors (BC)

Current Practices and structures

The public clients apply various means for reducing CO_2, and various contract modes, for different reasons. There is governmental regulation regarding reduction aimed at, among other agencies, the Swedish Transport Administration (STA), which requires measurements to create a baseline (R7). STA apply (or has applied) around 40 different schemes for reducing CO_2, such as energy plans that contractors need to submit when bidding for contracts, environmental zones with varying minimum demands for low emissions machinery depending on area, mandatory eco-driving training, environmental bonuses for using more efficient machines and climate calculations for larger projects (Swedish Transport Administration, 2012a; 2012; 2013; 2014).

STA has agreed with the three major cities in Sweden on shared environmental procurement demands for construction work, including a systematic environmental management scheme, an environmental plan and demands for what kind of fuels should be used. The environmental zones produce threshold levels that contractors need to surpass in order to bid for contracts. Moreover, many (large) clients have a tradition of work in-house, which has created a detailed technical knowledge (R7), as well as aesthetic requirements, that results in detailed design requirements (R4a & R4b). This is why even large clients have small experience and knowledge in functional procurement.

STA demands that fuel consumption is measured for each large project but this data is not linked to work achieved or not used for planning or procurement. BCs also argue that clients are not willing to pay for internalizing CO_2-emissions. CEs argue that environmental bonuses are good for replacing older machines with newer ones but that the bonuses are not passed on to CEs. BCs argue that threshold levels and detailed designs produce low incentives and a low degree of freedom for building contractors to be innovative in their approach to reducing emissions (Swedish Transport Administration, 2013). Once a contract is won, there is no further incentive to reduce emissions during the contract period and no opportunity to be innovative. Demands vary a lot and they are not followed up.

Eco-driving courses are effective only if there is an incentive to use the new knowledge. Vägverket (the Road agency, now merged with railway agency Banverket into Swedish Transport Administration) and other agencies was given a governmental commission regarding "economical driving" for larger construction machinery (Vägverket *et al*., 2010). The report suggests mandatory training in all driving schools and that economical driving is a mandatory requirement for public procurement. Mandatory eco-driving training is easy to demand and to follow-up but its use need to be supported by feedback and incentives. The report states that economical driving is achieved through various managerial means: leadership, good measurement of results, documented follow-up and motivation for drivers. However, during the workshop it was argued from providers that the suggestions for management initiatives need to be integrated with contractual incentives, that is, CE management also need motivation for their efforts.

The climate calculations are made in advance for projects over 50 MSEK (from 2015) and they are used for learning to improve planning and to reduce emissions (R7, Swedish Transport Administration, 2014). The calculations identify "hot spots" with high emission levels within projects and to produce a base-line, or threshold level, for contractors. The contractors will be tasked with reducing the hot spots during the contract period. The new threshold will be placed 15 percent below that of the reference projects. Currently, it is unclear what kind of incentives that would be coupled to the climate calculations.

Possibilities to enhance a result-oriented business model

BCs argue that functional procurement contracts (procuring a service such as a mobility possibility rather than a road) or turnkey contracts are best suited to reduce emissions, providing incentives and degrees of freedom needed for finding solutions (innovation). For example, during the workshop, they argued that build-and-maintain contracts provide good opportunities for a life-cycle approach to reducing emissions. In this way, the climate calculations could be used as baseline for functional procurement or turnkey contracts, with accompanying contractual incentives for reduction. This could be an efficient means to comply with the new law on energy mapping for large organizations, based upon the EU Energy Efficiency Directive (2012/27), which is part of the third national energy plan.

Need for knowledge, data and tools

Thus, there is already data and contractual means that could be used to stimulate energy reduction. However, there is also a need for easy to use LCC-data that could be incorporated into business calculations, as a means to internalize external costs for the use of construction equipment. These data and costs should be the same as those used in other transactions such as that between BC and CE so that efforts can be allocated to where they make best use and also rewarded accordingly. There is currently emissions data for different categories of machines but there is a need for data for machines in use, specific to each machine (R6). Clients need to ask for such data in their contracts (R8). They should replace demands for machines with a certain age for demands for a certain emissions volume per work achieved, CEs argue (R1).

Other options include a baseline for a maximum CO_2-volume for the whole construction period, coupled with contractual incentives to share the savings from further reductions between client and BC. Such a model has been put to use in a large transport contract for the Stockholm Water authority. These models enable BC to find the most efficient means. BCs also argue that BCs argued that clients need to remunerate them for solutions that are more expensive for them (R3). STA agrees and argues for solutions around risk sharing, at least for pilot projects (R7). Contracts need to include climate costs.

STA could couple emissions data with data from work being carried out. When costs are internalized into contracts, clients and BC may agree to a partnership where they share the savings from emissions reduction. Moreover, the contracts need to be constructed so that other partners can share the rewards for their contribution. For example, the rewards that a BC gets from reduction could partly be the outcome from efforts that the CE makes. That part should be rewarded accordingly as regulated by the contract. STA agreed that contractual incentives for reducing during construction are a promising model. CEs argued for trying in small scale and BCs that changes would not happen too often – it needs to be transparent. Risks could be shared through extra-work agreements.

Construction Entrepreneurs (CE) vs Equipment Providers (EP)

Current Practices

Currently, providers sell machines, often with one-year access to data. They offer eco-driving training and the support that CEs ask for. While advanced machines offer a lot of data on fuel consumption and use, most CEs do not use these for driving or for evaluating their performance.

The small size of many CEs makes the procurement cost for each machine a large investment. Drivers also tend to customize the design and use of each machine according to their working habits and experience: the machine is their personal working space and tool box, not like an interchangeable cockpit or operating theatre. Such customization might not be adding to efficiency, even less integrated into a concept. Drivers are often very specialized in regard to their machine and often not willing to let anyone else use it. They are also less willing to change machine to optimize fuel consumption - instead they change application when tasks vary.

Possibilities to enhance a result-oriented business model

Providers may provide eco-driving training and CE management might provide incentives for drivers to use it. Providers may provide technical support for efficient driving and for following up. There are advanced telematics systems for each brand but no one that integrates fuel consumption and work being carried out. There are also various systems that provide technical support for guiding drivers work such DynaRoad (DynaRoad, 2015) and systems that visualize drawings and the position of various parts of the construction equipment.

Need for knowledge, data and tools

The CEP currently provides access to machine data on their services through application programming interface and web portals. The access formats are in the manufacturers' own format or commonly available (AEMP, 2014) in the Telematics Data Standard. These two organizations aim to advance this standard through the ISO-system. Increased utilization of this standard could open up the software ecosystem both for advanced software service e.g. systems for oversight of construction sites as well for more focused apps for smartphones or tablets. One example could be excavator operator support or training. Different visualization techniques with or without combination of modelling models, e.g. maps, dashboards for key performance indexes could e.g. support reduction of the CO_2-footprint.

To this end, there is a need to be able to measure work and emissions or fuel consumption in real work and to relate these two data as well as to provide life-cycle data in forms that are useful for buyers at CEs and Providers. Manufacturers and providers could standardize working procedures and provide data that could be used for comparing packages between different providers. Current calculation programs available at the BCs could be used to this end.

Technologies for driver support could also be designed to set up individual goals for drivers to improve their outcomes (R2). Thus, there is a need for data concerning work being carried out and the corresponding climate impact for the whole life-cycle for the construction equipment, using in-built technology (R2). They could also be designed for self-learning systems that suggest moves for drivers such as changing gears.

Regulators (R) vs Public Clients (PC)

Current Practices and structures

There are several regulators in this field such as The Energy Agency as well as the Swedish Environmental Protection Agency charged with energy savings and environmental planning. These regulators issue various directives that are translated into various schemes, such those that STA is assigned with, some of them addressed directly to other actors in the value chain. Most of these schemes though are not directly related to the transactions involved with buying and selling construction work.

The major influence in terms of business models stems from the Swedish Competition Agency which until 2015 both oversees and advices on public procurement issues. Public procurement in Sweden has since the early 1990s been a predominantly judicial process, where low price has been the primary goal. The public procurement act stems from EU directives, primarily concerned with five legal principles: equal treatment of potential bidders; non-discrimination of foreign bidders; transparent and complete demands; proportional demands in relation to size and technicality of the procured objects; and mutual recognition of all member states regulations and the like. Moreover, there are governmental directives concerning innovation procurement, directly addressed to Swedish Transport Administration.

The procurement that STA currently performs is an effect of these various influences, as well as from strong internal technical and environmental competences. The approach taken varies between different projects such that there are different options and resources to be used among the schemes available: environmental zones, climate calculations etc.

Possibilities to enhance a result-oriented business model

Increasingly, public procurement has been concerned with environmental issues, supported by data, knowledge and tools from e.g. the non-profit company the Swedish Environmental Management Company (Sw. Miljöstyrningsrådet), most of which is now transferred to the National Agency for Public Procurement. Their support includes area and product-specific advice as well as a generic model for strategic purchasing from an LCC-perspective (R2). One of the areas is energy and climate. The experts consulted in this study argued that functional procurement do not need to be that special but that it is important to verify data (R5).

STA can use its vast array of expert knowledge within construction machinery, life-cycle analysis and climate reduction together with several of the existing schemes: climate calculations, innovation procurement, planning and design to support the implementation of result-oriented business models.

Need for knowledge, data and tools

During the workshop, the experts from Swedish Competition Agency suggested various means that STA could use to construct contract modes that support result-oriented business models: creating a baseline for verified CO_2-emissions (using the climate calculations) through using the fuel consumption measurements that procurers could use to remunerate BCs. This could be used to create contractual incentives for BCs. They also argued, in regard to the transparency principle, that there is a limit to how high demands can be: demands cannot be as high as to exclude most companies in a market. However, through cooperation between small companies, they are able to respond to demands. It is also necessary though that demands are followed up and that the follow-up process is transparent.

CONCLUSIONS

In summary, the current investigation suggests that a business model that is both profitable and reduces carbon emissions, which aligns business and environmental objectives, is best designed as a result-oriented integrated concept, where the provision of low-emissions machinery is linked with technical driver support, production life cycle data and contractual incentives.

There are current schemes in use among all the business partners that can support the design of such business models. These include climate calculations among both clients and building companies, eco-driving training, technical support that guides and visualizes drivers as well as turnkey or build and maintain contracts. Moreover, there are currently unused schemes that could be put to use such as functional procurement and contractual incentives to reduce emissions, advanced support technologies e.g. DynaRoad and existing data exchange systems for fuel consumption, vehicle use etc.

To enable the design and effective implementation of such business models, there is a need for re-arranged relations among the different partners in such way that their respective contributions to carbon emissions are aligned, both technically and with respect to risk-sharing and remuneration. This could be achieved through a number of measures:

1. **More knowledge about the efficient use of construction machinery and how technology could be better used to that end**. Construction machinery are complex systems with both hardware and software parts. For instance, automatic controllers that control both the speed of the main motor and the hydraulic pressure. These are optimised in respect with to the general machine performance. However, the fine tuning of these controllers could be done based on specific data for that single machine, not different from what a major truck producer do in their new line of trucks.

2. **Support systems within the construction machines for learning from using them**. For instance, if enough construction machine data could be recorded along with construction GIS-data, a digital twin of same machine type (a complex mathematical model) could be used to show how the machine was used by means of virtual reality. This could most likely give the driver new insights and the digital twin could also be used as a basis for training simulation.

3. **Verified measurements of emissions relative to work achieved. This enables computing the carbon footprint from actual work**. In our investigation we found that there is limited emissions data regarding for instance different excavators in the same size class and there is also a lack of emissions data for different use-patterns for different machinery i.e. an excavator doing work in cities relative to work in housing construction work.

4. **Inbuilt technology in construction equipment for comparing work achieved and carbon emissions**. Giving instant or near in time feedback has shown successful using principles for what is called gamification. It can increase the engagement of the driver to improve his or her work. Also, it can be used as input for discussions between drivers on common learning events.

5. **The design of a common interface for exchanging data across brands**. This would enable construction entrepreneurs with different brands of equipment to view and analyse all machines in the same software. Furthermore, it would enable construction entrepreneurs to forward information to the building contractors and to their public or private clients. A common interface would enable a much larger transparency regarding the resources used during a construction work or larger projects.

6. **Packaging machine data for business calculations. This makes it possible to compare different integrated concepts between different construction entrepreneurs**. For instance, for large project procurement, a public buyer could request the building contractor to present a calculation based on their own data for machinery in combination with a calculation based on different types of work in a project.

7. **Tools for improved planning and logistics at the workplace, enabling a more efficient use of construction machinery**. The benefits from this could be to get early updated time estimates for a particular work or for instance to see if ordering another dumper truck would make the work efficient. Better planning tool could also for enable a cooperation between construction entrepreneurs to have a common pool of drivers, making it possible for a higher degree of utilization the machines than a single driver can provide.

8. **Standards for different uses (such as excavating, loading and shuffling) that could be used to create baseline data for work and emissions, as a ground for contractual incentives.** This could be a used as tool in the procurement support the setting reasonable demands in the tenders for the work, regarding man power as well as machinery and machine efficiency.

9. **Contracts that include measurements of the carbon footprint and incentives to reduce it.** This would give the construction companies an incentive to hire construction entrepreneurs that train drivers continuously and that continuously follow up usage of the machines.

10. **Contractual schemes where clients contribute to share risks for experiments in carbon reduction**. Contractual schemes has already been used that enables building contractors to determine how a road with certain limits are drawn in a landscape to save construction masses, digging time and transport distances. A next step would be to attach a second criterion to also incentivize the reduction of CO_2 emission for a certain project or site.

There is a need for experimentation and stakeholder alliances to design and implement effective sustainable business models (Krucken & Meroni 2006). One example could serve as inspiration. STA defines a CO_2 budget based upon default calculations and carbon emission goals are set in the contract. Building contractors are free to reduce emissions in the most cost-effective way, comparing various solutions for the construction work, using life-cycle data and performance data for various construction equipment machines. Their performance is remunerated according to their results. The construction entrepreneurs are charged for a certain work to be made, including climate costs, based upon life-cycle data and performance data. Their performance is remunerated by the building contractors according to their results. The construction entrepreneurs offer a machine with appropriate technical support for guiding and learning from work, assign a proficient driver and remunerate them according to their performance in terms of efficient work.

The article reports a pilot study in Sweden within the construction industry. The findings can be generalized on three different grounds. First, generalization has been done using similarities. The public procurement principles that apply in Sweden are common to the EU which makes the conclusions regarding public procurement easily generalizable.

Secondly, generalisability is also allowed because the integrated concept is designed to support various technical means to reduce emissions, which makes it applicable in various situations with different possibilities, for example in sites with different carbon footprints for electricity use, differential access to and costs for renewable fuels, varying equipment standards or with varying ground conditions.

Thirdly, there are a few circumstances that makes the pilot case study an example of an "extreme case" that also provides generalizability to other industries and to other countries. That is, if the result-oriented business model can be made to work in this case, it should be applicable also in less extreme cases. The construction industry is different from many other industries due to low levels of standardization and innovation, partly due to the vastly varying conditions of use. This makes it difficult to design result-oriented business models construction entrepreneurs and low levels of renting of complex equipment compared with for example Germany and the UK, the design of such business models should be more difficult in Sweden.

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