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Can Material Passports lower financial barriers for structural steel re-use?

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Can Material Passports lower financial barriers for structural steel re-use?

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Abstract. The building and construction sector is responsible for more than half of global steel consumption. Recycling is common practice. Yet, this is an energy intensive process, even when using the best currently available technology. A strategy that avoids energy use for remelting and significantly reduces negative environmental impacts is re-use. Steel element re-use is technically feasible and economically attractive in certain cases. However, re-use rates in the UK remain low. Cost and timing are identified to be among the main barriers for re-use across the structural steel value chain. Re-used steel is estimated to be about 8-10% more expensive than new steel, taking into account all required reconditioning processes. This study investigates how data/information services like BAMB Material Passports can facilitate structural steel re-use in the UK by lowering financial barriers. It shows that relevant data has the potential of reducing costs in sourcing, testing, reconditioning and fabrication, ranging from 150-1000 £/t, depending on the re-use path followed (remanufacture or direct re-use of elements/structures). Key stakeholder groups are stockists and fabricators, which will be both the suppliers and customers of the data. It should be noted that data alone is not sufficient to overcome all barriers. Next to shortening or vertical integration of the supply chain, value redistribution across the chain can align incentives of different stakeholders. Regulations and perceptions (on quality) also play a key role. Finally, reversible design/design for dismantling can be a game changer in the transition towards more structural steel re-use, since it can significantly reduce deconstruction costs.

Keywords: business case, structural steel re-use, material passports, data.

1. Introduction

The building and infrastructure sector consumes more than half of the global steel production— a number that is continuously growing [1]. Once structures reach the end of their service life, up to 93% of their structural steel elements get recovered and recycled in the UK [2]. This is obviously good news in terms of material conservation and prevention of raw material extraction. However, the recycling process is energy intensive, even when using the best currently available technology [3]. It only saves approximately half of the energy compared to the production of new steel [4].

Steel re-use, on the other hand, has the potential of saving up to 96% of environmental impacts compared to new steel [3]. Technically, structural steel can be well suited for re-use. Only when exposed to fire or fatigue their physical and mechanical properties degrade over time [5]. Today around 78% of all steel scrap produced in the UK is exported for recycling [6]. This includes structural steel scrap from buildings, which is very valuable for the steel mill given the large volumes and rather constant properties, and therefore more expensive than other steel scrap. Dunant et al. (2017) estimated that structural steel scrap arising from buildings could cover between 40 and 80% of structural steel demand if its export for recycling is avoided [7]. Furthermore, there is a substantial price gap between new steel sections (1000-1500£/t) and steel scrap ((100-200£/t) when taking into account all handlings required, suggesting significant profit opportunities for re-use. It was found that in specific circumstances like complete structure re-use or structure relocation savings might mount to 30% compared to the of using new steel [7].

Unfortunately, re-use rates in the UK are low (8-11% of heavy sections from demolition [7]) and still decreasing [8]. What are the barriers preventing people from turning to structural element re-use? The existing literature lists the most important ones faced by actors across the structural steel value chain, including traceability and re-certification of beams, sourcing challenges, lack of demand and the old/new perception [7] [9]. Re-use will not be considered if it is more expensive compared to new elements or if it results in delays of the project [7]. In the construction sector there is a lack of tools to support re-use strategies and allow overcoming the most costly barriers – assessing the properties of structural elements or searching for appropriate elements.

This study investigates the role of data platforms, such as Material Passports as developed in the Horizon2020 BAMB project, in facilitating this re-use. Materials Passports are sets of data describing defined characteristics of materials in products that give them value for recovery and re-use. This with the aim to increase or keep the value of materials, products and components over time and to facilitate reversed logistics and take back of products, materials and components [10]. The objective of this study is to determine to which extent the provision of relevant data, like in Material Passports, can incentivize value chain actors towards re-use of structural steel by decreasing the financial barriers they are facing, and what this data should look like.

The first section of this paper gives a brief overview of the methodology applied in order to get an idea on the cost implications of re-use for the actors involved. The second and third section are respectively concerned with the potential cost reduction opportunities of different types of data and the business opportunities for Material Passports. Next, the discussion section lists the limitations of data in the facilitation of structural steel re-use, as well as some other measures it might be complemented with, leading to a final conclusion.

2. Methodology

2.1 Structural steel value chain

Based on literature sources and interviews conducted between February and June 2018 with experts in the area of structural steel (including academia, stockist, fabricator and demolition contractor), the value chain for new/recycled and re-used steel was drawn and presented in Figure 1. Not distinguishing primary and secondary production, the mill sells steel to a stockist or directly to a fabricator. In the case of larger enterprises, stockists and fabricators are often the same company. The outer cycle of the chain, where buildings are demolished and the recovered elements are recycled, represents what is mainly happening today. To understand how the inner circles of direct re-use and remanufacture can be incentivized from a financial perspective, the cost structure was assessed in section 2.2.

2.2 Financial barriers re-use

Based on the work of Dunant et al. [11], Table 1 compares the minimum and maximum costs of operations across the value chain, in the case of new and re-used steel elements. It shows that steel re-use is currently approximately 8-10% (or £80-140/t) more expensive than new steel, mainly due to high costs of testing, reconditioning and deconstructing.

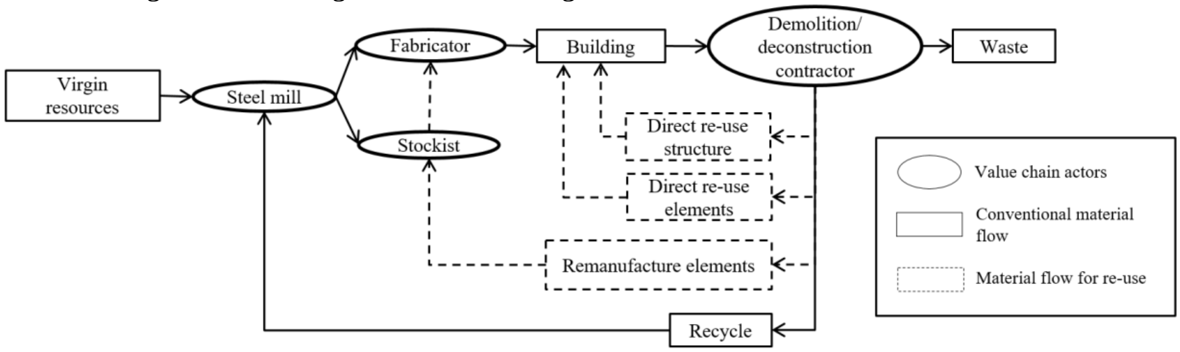

Figure 1. Value chain for structural steel

Next, assumptions were made about the actors bearing the listed costs in the case of remanufacture of elements. In this scenario, the role of the stockist changes considerably compared to the business-as-usual. While in the traditional value chain stockists mainly serve as tradesmen linking supply and demand (possibly taking into account a short lead time), they are now burdened with testing used elements in order to give quality guarantees to downstream actors like the fabricator.

Table 1. Cost comparison new and re-used elements.

Cost component	New steel beam (£/t)		Re-used steel beam (£/t)		Key actor
	Min	Max	Min	Max	
Striking down	-	-	120	165	Demolition contractor
Steel	530	750	200	300	Stockist
Standard operations	*110*	*110*	*110*	*110*	
Steel cost	*400*	*600*	*90*	*190*	
Premium uncommon sections	*20*	*40*	-	-	
Testing	-	-	145	175	Stockist
Reconditioning	-	-	100	200	Fabricator
Shot blasting	-	-	*15*	*55*	
Removing welds	-	-	-	*25*	
Removing end plates	-	-	*85*	*120*	
Fabrication	498	700	498	700	Fabricator
Administration	*50*	*65*	*50*	*65*	
Design	*55*	*80*	*55*	*80*	
Bolts/primer	*25*	*35*	*25*	*35*	
Erection	*120*	*165*	*120*	*165*	
Cuts/Welds/Drills/Shot blasting	*248*	*355*	*248*	*355*	
Transport & handling	20	25	65	75	Other
TOTAL	1048	1475	1128	1615	

Difference	*+80*	*+140*

3. Potential cost reduction opportunities and roles of data

3.1. Testing

One of the most important barriers to steel re-use are concerns related to steel properties [9]. Since the CE-marking legislation was introduced for the construction industry in 2014, this has become even more important. All steel structures have to be certified for suitability by the fabricator, which has implications for the elements used. When the age and producer of elements is known, properties can be found in design guides (such as the ‘Blue Book’ or ‘Green Book’ published by the Steel Construction Institute [12]). Often, however, the section or building age is unknown and/or actors do not have sufficient confidence in properties based on section dimensions and tolerances from the ‘Blue Book’ or ‘Green Book’. In this case either conservative assumptions might be made for the structural design [13], or third-party lab testing might be conducted.

However, as long as elements were not exposed to fire or fatigue during their service life, lab testing is not technically necessary [5]. Therefore identified useful original properties and usage history data to determine used steel element quality include the steel grade; weldability; source mill; production date; fabrication original building (details original building, section sizes, beam location, connection geometry); and usage history (loading history, building purposes, exposure to fire, deconstruction method).

If testing of used elements can be avoided by providing the information listed above, stockists can generate savings of 145-175 £/t, already making re-use financially more attractive than using new elements, from an overall supply chain perspective.

It should be noted that although the data listed above should be able to determine the quality of used steel, lab testing might still take place. Tests are often carried out for customer confidence and liability reasons. Fabricators or clients often desire an official test certificate for used elements, particularly given the obligation of CE-marking. This also explains why destructive and chemical lab testing is preferred over non-destructive testing with portable devices. Although the latter is much cheaper and can be performed on-site by the stockists, it does not provide the same level of confidence as third party lab certificates.

3.2 Reconditioning

Elements used in buildings are usually characterised by different lengths and sizes, holes, stiffeners, welds, and end plates [7]. They have to be prepared for re-fabrication, which comes at a considerable cost. As shown in Table 1, end plate removal is a very costly operation. In reality, ends are usually cut off to save costs, although cutting shortens the elements and reduces both the financial and re-use potential.

Coatings that include intumescent paint have to be handled with care. According to the stockist, additional shot blasting or grit blasting is required, since traces of existing paint can cause adhesion problems when over-coating, or is simply not desired by the customer for aesthetic reasons. When a beam with unknown coatings is recovered from an older building, extra cautious removal treatments are often chosen due to potential hazard of the unknown coating.

Providing data about the products used for painting and/or coating the original beam can help to reduce reconditioning costs: 1) it can be determined whether the original coating is suitable for the new application; 2) it can be determined whether over-coating will be compatible with the original coating, therefore whether its removal is necessary; 3) if the original coating still has to be removed, the most cost effective processes can be selected. The coating data required consists of the supplier tradename; technology used; date of application; applicator; and warranty.

Providing more certainty about the coating applied could decrease the barriers of re-use for fabricators and saves 15-55 £/t by avoiding unnecessary shot blasting or grit blasting. This saving alone is insufficient to incentivize re-use from a financial point of view.

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3.3 Deconstruction

If steel elements are to be re-used instead of handled as scrap and melted, a shift from demolition to more careful deconstruction is necessary. Deconstruction, which is currently only obliged in urban areas, is much more labour intensive than demolition, since more handling is needed for each element and buildings are usually not designed for deconstruction. Since more actions may need to be performed manually instead of by machinery, there could be also additional costs related to health and safety [7]. Reversible design and construction methods are needed to reduce deconstruction costs. When these methods are implemented, data could be used to provide e.g. deconstruction guidance.

Next to the cost implications, the added value of reusable steel (compared to scrap) is not captured by demolition contractors at the moment [11]. They are not paid more for intact used elements than for steel scrap. Value redistribution across the supply chain will be necessary to incentivize proper deconstruction.

3.4 Sourcing

Availability of used elements is indicated as one of the most important barriers of re-use. Searching for elements or structures in the desired quantities, quality and dimensions is time consuming. By centralizing supply and demand in a data platform, sourcing costs can be reduced by limiting searching time and cost for fabricators, engineers and/or contractors.

The total savings generated by the provision of data amount to 160-230 £/t for refurbish/remanufacture. If a supply-demand data platform can further facilitate direct re-use of complete structures or individual elements in their original condition, big savings of up to 373-590 £/t could be achieved by avoiding reconditioning and certain fabrication costs, making re-use far more interesting from a financial perspective than the use of new elements.

4. Business opportunities for Material Passports

Based on the findings in the financial analysis, three business opportunities for data in structural steel re-use were identified, as summarized in Table 2. In the case of remanufacture, the main value proposition of data lies in cost savings by avoiding testing and unnecessary shot blasting, given that material properties and coating data are available and meet design requirements. When turning to direct re-use of elements, Material Passports mainly provide sourcing advantages. It is significantly more convenient to find elements with the desired properties and dimensions if this information can be consulted in a database like Material Passports. Next to this sourcing advantage, more extensive cost savings can be realized when directly re-using elements. This by avoiding testing, reconditioning and certain fabrication activities (Bolts/primer and Cuts/Welds/Drills/Shot blasting). Moreover, when re-using complete structures even erection costs can be avoided.

Table 2. Business opportunities of data in structural steel re-use.

Use case	Customer group	Value proposition of data	Added value
Direct re-use of structures	General contractors	Sourcing advantage	Up to 1000 £/t
Direct re-use of elements	Fabricators	1. Sourcing advantage 2. Cost reductions (lower testing, reconditioning and fabrication costs enabled by technical/usage data)	Up to 800 £/t
Remanufacture of elements	Stockists/Fabricators	Cost reductions (lower testing and reconditioning costs enabled by technical/usage data)	150 -250 £/t

In table 3, the needed data were listed, together with an overview of the data provider.

Table 3. Overview supplier/customer Material Passport.

Data requirement	Supplier
Material properties	Fabricator original structure
Steel grade	
Weldability	
Source mill	Fabricator original structure
Production date	Fabricator original structure
Fabrication original building	
Details original building	Architect(s)/Structural engineer original structure
Section sizes	Fabricator original structure
Beam location	Structural engineer/Fabricator original structure
Connection geometry	Fabricator original structure
Usage history	Facility manager original building
Loading history	
Building purpose	
Exposure to fire	
Coating	Fabricator original structure
Supplier tradename	
Technology used	
Date of application	
Applicator	
Warranties supplied	

Tables 2 and 3 show that the stockists and fabricators are the most important actors for data-supported structural steel re-use from both the supply and the demand side. It will be in their interest to provide the required data, as they know they will also benefit from it extensively.

Nevertheless, their willingness-to-pay has to be identified. It was highlighted in the interviews that some large fabrication companies may use the cost-plus pricing method, and will therefore be less interested in cost reduction opportunities. Furthermore, an important challenge may be how to incentivize data suppliers, since their efforts are needed today while benefits only exist in the long term future.

5. Discussion

Providing data in the form of Material Passports can result in considerable cost savings across the value chain, but they are not equally spread. In order to encourage re-use, there should be financial incentives among all players involved.

For the remanufacture path, the savings generated by data are mainly in favour of stockists, who are already incentivized for re-use due to a lower buy-in price compared to new steel. For fabricators, data can provide some limited savings in reconditioning costs. Due to the remaining reconditioning costs, however, re-use will still be more expensive for fabricators than new unless there is a possibility for direct re-use. Demolition contractors, on the other hand, do not have any cost saving benefits, their costs will increase considerably when deconstructing instead of demolishing.

Consequently, re-use will only take place more regularly if cost savings can be redistributed across the value chain. Figure 2 illustrates how the savings mentioned earlier can be redistributed across the value chain in the 'worst-case scenario' of re-use; remanufacture of elements. This approach, where the stockist pays a higher price for used steel to the demolisher and charges a lower price to the fabricator, serves purely as a hypothetical example to show how every actor involved can be incentivized for re-use, by redefining the transfer prices between actors and in this way redistributing some of the profits earned by the stockist.

Assumptions made:

- Four scenarios are taken into account:
    1. Using new steel elements in construction, demolition of buildings at end-of-life.
    2. Remanufacture steel elements.
    3. Remanufacture steel elements with access to a Material Passport.
    4. Remanufacture steel elements with access to a Material Passport and redistribution of cost savings across the value chain.
- Averages of the minimum and maximum costs listed in Table 1 are used in order to limit complexity.
- Transfer prices between stockists and fabricators, and fabricators and customers are not known. As a starting point, their revenue is assumed to be equal to the cost they are facing in the case of new steel, resulting in zero profit for this scenario.

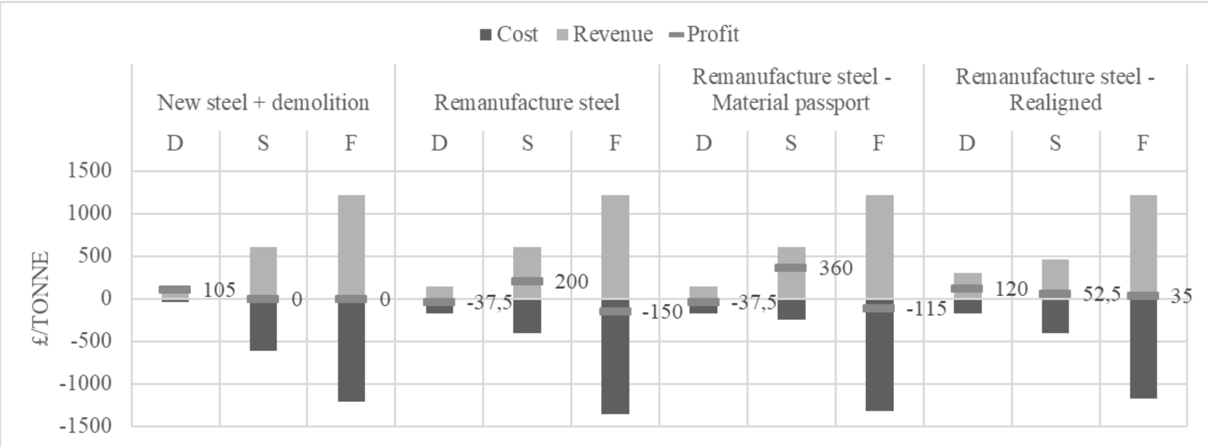

Figure 2. Cost redistribution across value chain.
D = Demolition contractor; S = Stockist; F = Fabricator.

Although the theoretical feasibility of incentivizing the complete value chain towards the structural steel remanufacture is illustrated, these incentives may still not be strong enough to scale up re-use in practice. One way to address this is limiting the amount of actors involved in the chain for re-used steel, by shortening the supply chain or vertically integrating it by combining different roles. In this way there are less players to distribute costs among. Design aspects like reversible building design, including reversible connection methods, could further incentivize structural steel re-use by reducing deconstruction costs and time, improving working conditions and the quality/value of recovered components. Furthermore, as mentioned repeatedly throughout this study, direct re-use of elements or complete structures would be the most attractive in terms of both financial and environmental benefits. In reality, direct re-use will likely remain rare unless there can be standardization of steel element lengths and connections.

6. Conclusion

This study draws the encouraging conclusion that Material Passports can contribute to lowering the financial barriers related to structural steel re-use and bring added economic value to the building industry already under today’s conditions. Their core value proposition is cost reduction, including sourcing, testing, reconditioning and certain fabrication costs. The highest added value will be achieved in direct re-use, instead of remanufacture.

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However, data alone is not sufficient to overcome re-use barriers. It should be noted that stakeholder engagement, as well as provision of scientific evidence increasing confidence in steel properties based on data is needed to establish common recognition of such added value, given that regulations and perceptions (on quality) pose significant barriers against re-use. Furthermore, value redistribution across the value chain is necessary to align incentives of the actors involved.

The business case can become much stronger if the supply chain for structural steel can be shortened of vertically integrated, and if re-use is taken into account from the early design stage of both buildings itself as of the structural elements used. Reversible building design and standardization of elements are potential game changers in the transition towards more structural steel re-use, since they can extensively facilitate the deconstruction process and direct reusability of elements and structures.

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