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# How Does Circular Economy Disrupt Business Models: the Case of Ballast Reuse in Railway Projects

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**Abstract.** The European rail infrastructure industries are incited to rethink their supply chain to achieve carbon neutrality by 2050 (European Green Deal). This leads them to undertake a paradigm shift from a linear to a circular economy based on reusing and recycling materials.

However, industries may be reluctant to invest in new circular models when they lack in estimating the potential benefits and costs of the new circular businesses. Nevertheless, the Ellen MacArthur Foundation argues that a circular economy develops new and strategic opportunities and generates benefits if well thought out.

This paper analyses the economic impact of moving from a linear to a circular economy, focusing on the ballast reuse for rail regeneration projects for the case of SNCF Réseau. We propose a multistakeholder activity-based costing approach and apply it to three ballast supply scenarios.

The results show that reusing ballast generates winners and losers. While it can be economically attractive for a project to reuse its ballast, it becomes more complex to determine the profitability of reusing ballast for sharing between different project sites; additional parameters should be considered, such as the distance between sites or to ballast pits as well as other environmental costs. The paper thus argues that circularity does not always equate to sustainability. The deployment of a circular economy should require a systemic vision that not only allows one to pilot a project but also to map and interact with its industrial environment.

**Keywords:** Circular economy, Railways, Ballast reuse, Activity-based costing, circular supply chain

## 1 Introduction

The ecological transition is prompting rail infrastructure managers to rethink and innovate their supply markets. For example, the French railway infrastructure manager, SNCF Réseau, has targeted collecting 100% of the structural materials used in railroad construction (rails, sleepers, ballast, and copper) for recycling. The company thus undertakes a shift from a linear economy based on the end-of-life concept to a circular model based on reusing and recycling materials.

Despite SNCF Réseau's stated ambitions, the literature tells us that such a transformation can be challenging due to barriers, such as the need for more communication between stakeholders [1], or the capacity to invest in new circular models [2]. However, the main obstacle concerns the lack of estimation of economic benefits [3].

Economic benefits are either the main driver or the primary barrier to adopting circular models [4]. Companies are reluctant to invest in new circular models that may be costly in the short term or economically unprofitable in the long term. However, if well designed, a circular economy may develop strategic opportunities while generating benefits.

Several tools and methods exist for estimating and subsequently improving the economic (and extra-financial) impact of integrating circular activities into companies. These methods are based on weak sustainability, where sustainable development capitals are substitutable [5]. These methods can make more explicit the trade-offs involved in achieving the best overall corporate performance, i.e., the best strategy and organization of resources. However, this point of view is not always shared in the literature, as it can be considered anthropocentric when the interest driving the company's change is economic rather than environmental [6]. In this article, we hypothesize that linking circularity to economics can facilitate corporate decision-making and change management. The monetarization methods provide an evaluation criterion for product and project design, allowing industrials to compare their different strategies regarding a standard reference and guiding their choices toward the optimal solution from an economic, social, and environmental point of view. However, we do not mean economic profitability should be the only motivator for moving to circular businesses.

Traditional economic evaluation methods include cost-benefit analysis [7], generally used on projects to measure the socio-environmental impact of a project; the activity-based costing approach [8], used to estimate the cost of a product through the activities carried out to design it; or lifecycle costing [9], revealing the cost of a product throughout its lifetime.

This paper adds to the literature an example of the impact of adopting circular business models in companies. Our research is based on the action research paradigm [10] used in the literature to solve a problem of real situations with continuous transformation thinking. More specifically, we focus on the monetary impact of ballast reuse in railway projects. To this end, in section 2, we adapt the activity-based costing approach to multiple stakeholders. The results of this approach's application are presented in section 3 and discussed in section 4.

## 2 Methodology

The research was conducted during two months at the end of 2022 in SNCF Réseau under the lead of two in-house experts in charge of deploying ballast reuse in railway projects and with the help of other experts and based on the internal investigation and document analysis. The work aimed to study the direct costs and profitability of reusing railway components, in this case the ballast, and how the reuse process can lead to the introduction of new ways of proceeding within the company.

That is why, this paper compares the profitability of three ballast supply models that can be used in a railway regeneration project: (1) the conventional linear model where old ballast is removed and replaced by a new ballast from external quarries; (2) a circular model where the ballast of a project site is reused onsite; (3) a second circular model where a project site transfers its old ballast to another project site to be reused. We focus in our analysis on the economic impact on the internal stakeholders in the company regarding these three models.

Since the purpose of our work is to understand the potential improvements enhancing ballast reuse at a significant level in the company, we decided to use a multistakeholder activity-based costing (we will call MS-ABC) adapted for industrial projects.

The traditional activity-based costing (ABC) approach is used in the literature for assigning direct and indirect costs to an industrial product, considering the activities carried out to manufacture this product [11]. ABC contrasts with conventional costing systems as it considers that a product consumes activities that consume resources. Over the years, it has acquired the ability to drive change in product design and manufacturing processes as it can be used as a decision-support information system [12], identifying potential cost drivers. ABC is composed of two stages. The first one consists of identifying the main activities and assigning their costs. The second stage allocates each activity's cost to the product.

ABC has inspired other methodologies such as Feature costing [13] based on the variation of costs according to the different possible features of products. More recently, [12] have proposed an ABC based on matrix multiplication that transforms the two ABC steps into two matrices, which combination represents a product-resources matrix. Finally, time-driven ABC has also been used, arguing that costs and revenues depend on resources and time [14].

In this research, we choose to use ABC since it considers that a product is a succession of activities, which also defines a project. However, as rail projects may involve several internal stakeholders, we needed to adapt ABC to attribute each activity's cost and benefit in a ballast reuse project to the stakeholder concerned.

Figure 1 presents the four steps of our MS-ABC. For each ballast model, the methodology consists of (a) mapping the potential internal stakeholders; (b) unfolding the activities executed in the model; (c) assigning activities to the stakeholders; and (d) attributing the cost or benefit of each activity according to each actor, knowing that the cost of an activity may depend on many variables. For example, the cost of transporting ballast to project site depends on the transportation mode. In this paper, we only focus on direct costs, i.e., we do not consider monetary values such as the cost of carbon

emissions. In the end, a comparison of the three ballast supply models allows us to assess the profitability of each of the model regarding a particular stakeholder. Our methodology differs from cost-benefit analysis in that it calculates profitability per activity to a given stakeholder. It also differs from lifecycle costing in considering an activity as a transaction between stakeholders.

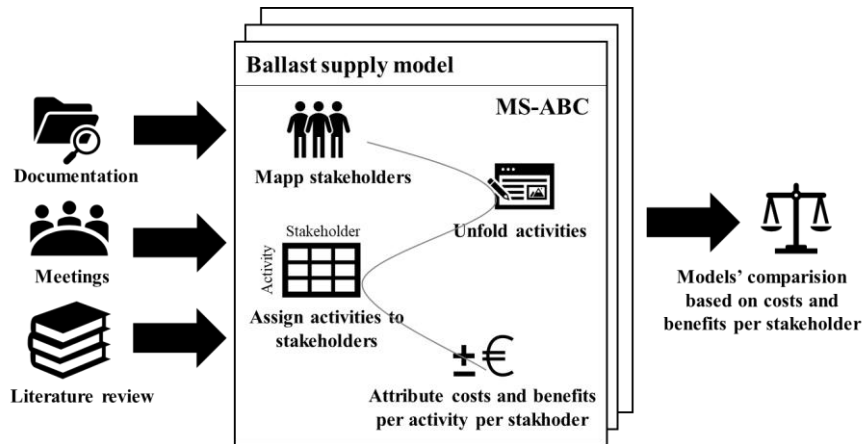


Fig. 1. Overall methodology

### 3 Results

The methodology is applied in parallel to the three ballast models described in the previous section. The final results are shown in Figure 2. For reasons of confidentiality, only standardized costs have been displayed, while the ratio between them remains valid. We mainly observe that:

- For the standard ballast supply model (BM1), two main entities within the company are involved: an internal supplier responsible for purchasing and trans-shipping ballast that is finally invoiced to a project. Note that the supplier's profit depends on the ballast transported, representing a significant project cost.
- We found no internal supplier for the second model (BM2), which consists of reusing ballast onsite (assuming 100% of the ballast is reused). The project considerably reduces its expenditure, which now depends on ballast screening and washing. This represents a loss for the supplier.
- In the third model (BM3), a supplier project supplies a buyer project (free of charge). The supplier project gains nothing (voluntary model). The buyer project's costs are lower than in the standard model (BM1) but still dependent on ballast transport (in this scenario, the project makes a profit). Note that, in this model, the internal supplier plays no role, which represents a loss for him and a potential impact on other projects using the standard model.

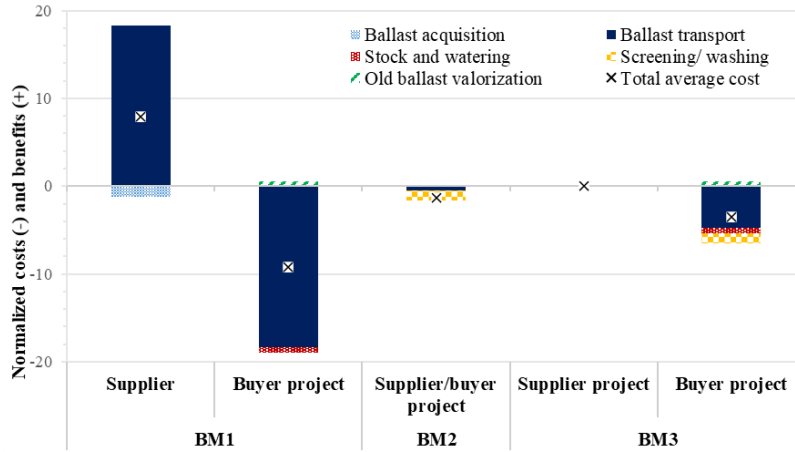


Fig. 2. Costs per ballast model, activity, and stakeholder

## 4 Discussion and Conclusion

The results show that the adoption of circular models upsets current balances as it can generate a win-lose situation. For example, in our case, the internal supplier is affected when two projects collaborate, leading it to rethink its role in the new supply models.

We also find that on-site ballast reuse (BM2), if ballast's quality permits, is the most economically profitable model for a project. Therefore, we can consider that when a project manager is well informed and accompanied by environmental experts, he will have no reason not to reuse the project's ballast. This solution could easily be deployed in industry on a large scale.

BM3 shows that voluntariness is the main factor for exchanging ballast between projects since there is no economic transactions between the two projects. We argue, here, that this can hinder the industrialization of circular models since that the supplier project has no economic incitation. We can thus imagine creating a marketplace for buying and selling ballast. This needs to fix a new way of calculating the ballast economic value as well as to promote new processes in the company. Indeed, we note that ballast transport is highlighted as the most impacting activity in all models. It represents the most expensive activity. It depends on many features, such as the transport mode or the distance between quarries or project sites. During our data collection, we analysed the scenarios of ballast transport. We noticed that the standard model BM1 may be more profitable for a project than the circular BM3 if the project is near a quarry. In addition, when calculating the carbon emissions of ballast supply, we find that transport is the leading emitter activity. In other terms, depending on the features, circularity does not always imply sustainability since BM1 may sometimes be less polluter than BM3. This leads to performing our actual methodology exclusively based on direct costs. To assess the overall profitability of circular models, we need to integrate other indirect costs linked to carbon emissions or ballast scarcity. Although the literature on environmental monetarization is rich, we noticed that project managers only sometimes understand the

proposed economic values. That is why we restricted this study to direct costs in a project budget. We emphasize the need for more disclosure on these issues. Nevertheless, our methodology is interesting in allowing us to represent the gains and losses per stakeholder. It allows managers and experts to understand the possible conflicts that could emerge when designing the business models.

To conclude, deploying circular models must be economically profitable but the economic criterion is not enough. As we have shown, circularity is not synonymous with sustainability. Companies therefore need to innovate and train project managers to enable them to manage a new, shifting, and complex project environment.

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