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ECONOMIC FLOW ANALYSIS OF CONSTRUCTION PROJECTS TO SUPPORT SUSTAINABLE DECISION-MAKING

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Abstract

Economy is one of the three pillars of sustainability and one of the parameters taken into account by many green building labels. In the construction industry, there exist many methods that evaluate the project cost; however, none of the current methods takes into account the location of the economic flows or the final stakeholders that benefit from them. This paper proposes a new methodology for tracing the economic flows of a project, by classifying costs into 5 categories: labour, materials, energy, infrastructure, taxes and overhead and in two levels: local and regional. The aim is to facilitate economic decision making for local authorities, construction managers and project investors and to make the social dimension of these flows and the generalized impact of the project on the local society apparent. The applicability of the new methodology is tested through some case studies. It is observed that such an analysis provides useful insights with respect to the economic flows going to direct labour vs overhead and taxes as well as regarding the spatialized distribution of the cost of a project.

Keywords:

economic flows; construction cost; labour; materials; taxes and overhead

1 INTRODUCTION

The demands of society for a sustainable development have placed strong emphasis on the ecological aspect of construction projects. The assessment of the environmental impacts of a project is widely performed with the help of Life Cycle Assessment [1], [2]. At the same time, the other two pillars of sustainability, economy and society, need to equally be taken into account in the planning phase. The assessment of the economic and social impacts is underlined by many sustainability labels and is part of the Sustainability Life Cycle Assessment in an attempt to provide an overview of the effects of a project.

With respect to the economic impacts, there exist many methods which are used to facilitate economic decision making in a project and are related to the evaluation of cost at different phases and levels of activity. Among the most widely used methods are Life Cycle Costing [3], Supply Chain Management [4], Material Flow Cost Accounting [5], [6] and Input – Output Analysis [7], [8].

However, none of the above methods can provide organized information of the flows of money in a project, their spatial characteristics and who the final recipients are. For this reason, we developed a new way of assessing the economic relationships in a project in order to understand the economic transformation of the society. This new methodology presents in a visual way the economic flows by categorizing them in broader classes. It is efficient in capturing the various transactions in the project and making visible whether the construction is labour intensive or relying mostly on overhead. It can also reveal whether the project is beneficial for the local community and contributes to its economic development. Therefore, it can facilitate economic decision making for investors and project owners, who can trace the route of their investment and identify the final recipients and make conscious choices that will affect the “social” return on their investment (the social groups that will benefit from it). It can also provide a map of the economic and, to an extent, social relationships between the different stakeholders of a project. A description of the methodology follows, accompanied by two case studies: the construction of a stone bridge in France and a building complex made of stone in Greece.

2 METHOD

In order to provide a framework for studying the economic flows in a project, we adopted the tiered approach of the supply chain management. Every tier (Figure 1) corresponds to a different level of analysis: project level, local, national and general level. The first tier of the model (project level) assembles all the costs incurred in the specific project. These costs are then distinguished to local and national in the second tier, depending on whether the manufacturer or stakeholder is locally or nationally located. The third tier represents the project costs and is similar to the first tier, but the cost categories include both direct and indirect costs. For example, the labour category includes not only the salaries of the employees working on the construction site, but also the indirect labour required in order to produce the materials to be used in this project (concrete, steel, glass etc.…).

Regarding the cost breakdown structure, we defined the following 5 components of cost, in accordance with the categorization followed in previous studies [3], [9], [10], [11]:

- Labour. This category includes the employees' salaries and all expenses related to their health and accident insurance, social security and the contribution to the pension scheme.
- Materials. This category encompasses all costs related to the purchases of the materials used in the construction process, excluding VAT.
- Energy. Here belong the expenditures related to fuel and electricity. Transportation is indirectly taken into account in this category.
- Infrastructure. This category includes all fixed and intangible assets of the company, which are indispensable for the production process. For example, the rent or lease of office or equipment and the depreciation and maintenance of machines. Here also belong the expenses related to the repair or maintenance of the infrastructure.
- Taxes and overhead. As overhead costs of a project could be classified the head office expenses, head office staff wages, taxes, fees, automobile expenses, financial costs, uncollected receivables and miscellaneous [12], [13].

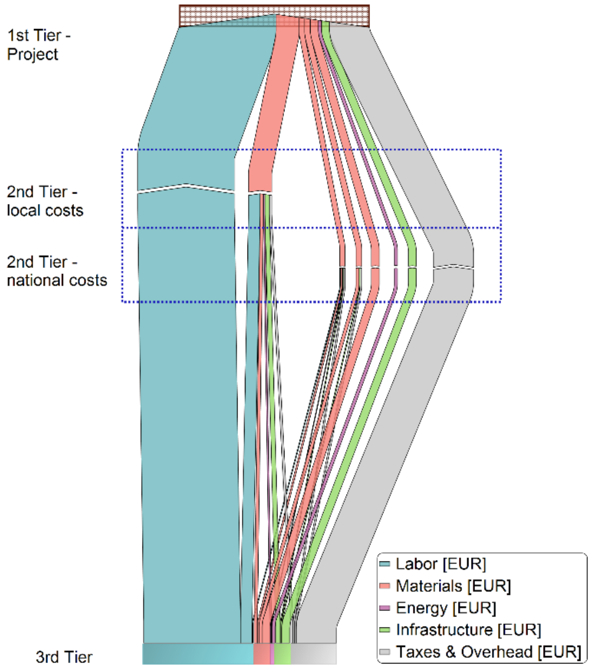

Fig. 1: Example of an economic flow diagram.

Figure 2 shows the source of data for each tier of analysis for already completed projects. Project invoices can provide us with data for most of the project costs, namely labour, materials, energy as well as the taxes paid and the overhead costs incurred (such as office and automobile expenses). Regarding the infrastructure used for a project, this can be allocated to the specific project in proportion to the time it has been used, considering the whole life cycle of the infrastructure.

In order to break down the manufacturing cost of each single material to its components, for the second tier of analysis, we have recourse to the corresponding production companies and to their income statement. In this way, we can determine which part of their production costs went to labour, materials, infrastructure etc. Any external charges, i.e. payment to subcontractors, included in the income statement are excluded from our analysis. In most of the income statements, this amount is less than 7% and most likely related to overhead or labour costs. For a complete and thorough assessment, the method that should be followed would be to find the subcontracting companies and analyse the amount paid to them with respect to the 5 categories.

If an analogy to Life Cycle Assessment (LCA) is attempted, then the first tier of analysis in our methodology, where data is extracted from the specific project invoices, would be similar to the foreground data collection. The second tier of analysis could be seen as collection of generic, not project specific data. This is close to the background data in LCA, which is usually based on generic databases and contains average values regarding the Life Cycle Inventory of various processes (e.g. Ecoinvent database [14]).

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Finally, the third tier of analysis consists of the addition of the quantities of the second tier and allows to gather all direct and indirect contributions in each category.

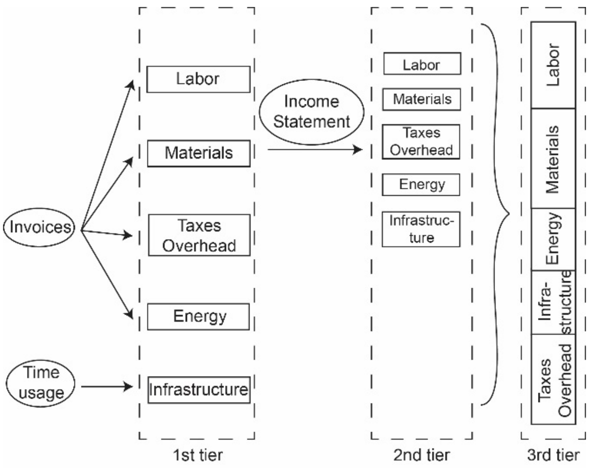

Fig. 2: Source of data for each tier of analysis.

3 RESULTS

The methodology presented above was applied to two case studies: the construction of a stone bridge in France and a building complex made of stone in Greece.

3.1 Construction of the Chaldecoste Stone Bridge

Project Description

The first case study was the project of construction of the Chaldecoste Bridge, in the south of France. The new stone bridge has a span length of 6 m and a width of 4.8 m (Figure 3).The stone solution was preferred, because the mayor wanted to use the local resources and the local workforce and respect the vernacular architecture [15]. Its construction was performed by four local artisans under the guidance of the engineering office Sétra and IFSTTAR (French Institute of science and technology for transport, development and networks).

Data collection

Regarding the first tier of analysis, the economic data of the project enabled us to categorize the costs into the 5 defined categories. The remuneration of the design office was classified as national overhead. Although for a full analysis we should further breakdown this amount to labour, materials, taxes etc., due to lack of information this amount was carried forward to tiers 2 and 3 intact as taxes and overhead.

With respect to the materials used for the construction of the bridge, these were (Figure 4): stone, backfill, formwork, cement, sand, lime, earthwork and coating. The cost breakdown at the first tier was performed based on the project invoices, while for the second tier, we extracted data from the financial statements of the relevant companies. For example, the cost allocation for concrete was based on the income statement of the French cement and concrete producer, Lafarge. When no statements were publicly available for a French manufacturing company, an international company of this field was selected for performing the cost breakdown. Finally, concerning the formwork production for the bridge, since no publicly available data could be found for the production of the material, the total economic flow was assigned to the “Material” cost category and carried forward “as is” to the other levels.

Results

The Sankey diagram (Figure 4) shows the costs repartition. At the third tier of analysis, labour costs amount to 68% of the total project costs. Material costs account for only 9%, energy for 1.5%, infrastructure for 8% and taxes and overhead for 13.5%. Regarding the cost breakdown between local and national, the construction of the stone bridge induces a flow of 77.6% of the total project cost going back to the local community.

Fig. 3: View of the Chaldecoste bridge.

3.2 Construction of a complex of 5 independent stone houses in Nafplion

Description of the project

In the second case study, we examined the construction cost for a complex of 5 independent stone houses in Nafplion, Greece. The structure of the houses is made of reinforced concrete and the walls from brick and stone (Figure 5). Stone was selected for the construction, because it is a characteristic material of the Greek landscape and is largely available in the area. Local crew was preferred for the construction and a local engineering office designed the complex and issued the permits. However, the accounting office hired was situated in Athens.

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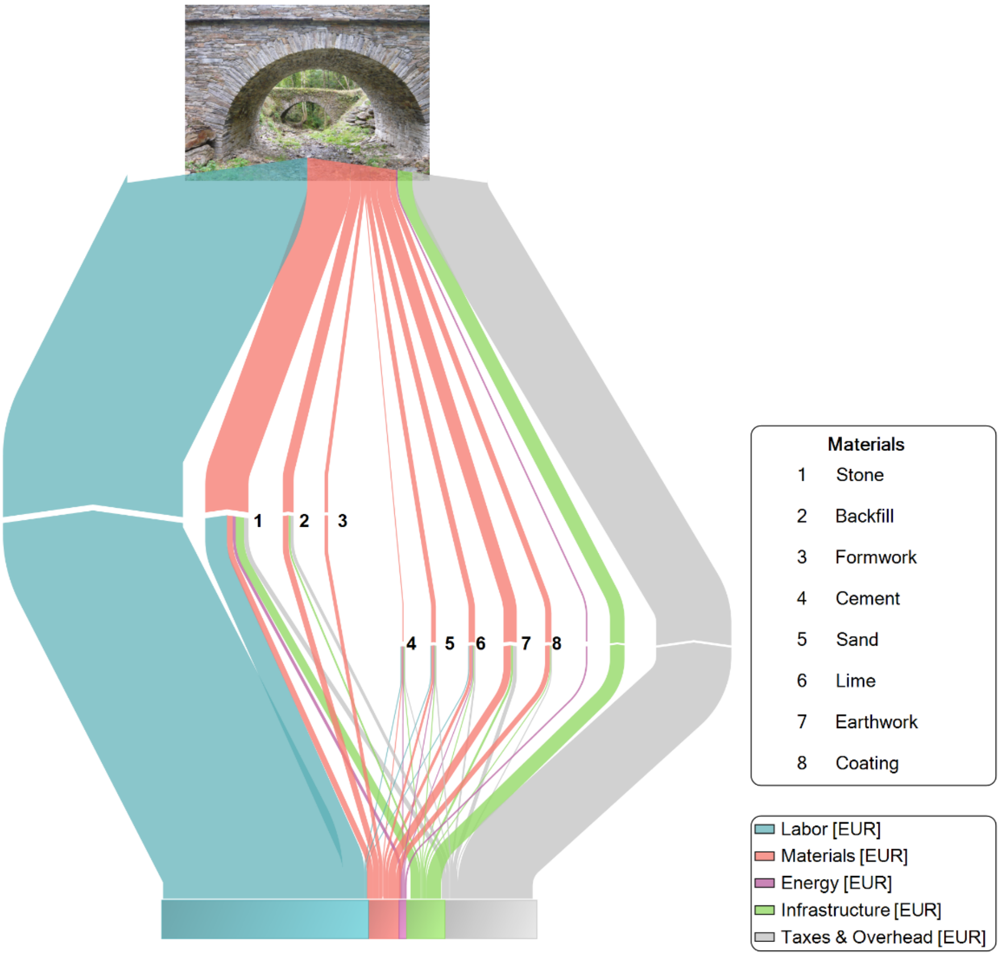

Fig. 4: Economic flow diagram for the construction of the Chaldecoste bridge.

Data collection

General expenses include the engineering office, the accounting office and the legal services for the project. In the national materials, some products which had a total contribution of less than 5% to the overall project costs, namely plumbing materials, bathroom appliances and roof tiles, were aggregated under "Others" and as with the case study of the stone bridge, the total economic flow was assigned to the "Material" cost category. Since these costs do not represent a significant percentage of the total expenses (less than 5%), the error is minimal.

Results

The cost allocation for the project is shown in Figure 6. Labour costs in the third tier amount to 51% of the total project costs, materials to 13%, energy to 5.5%, infrastructure to 7.5% and taxes and overhead to 23%. In addition, it is observed that the construction of the stone houses, with the employment of local workforce, results in 69.5% of the total project cost going back to the local community. It should also be considered here that many materials that are not produced in this area, had to be transported from outside the region, thus increasing the percentage of national costs.

Fig. 5: View of the complex of stone houses in Nafplio.

4 DISCUSSION

The two previously presented case studies show the breakdown of the project costs in national and local contributions. The analysis can help derive a series of observations with respect to the cost structure of the projects, the main stakeholders benefiting from them and also the utility of the projects for the local community from an economic point of view.

Regarding the main stakeholders of the projects, in both cases, labour costs are significantly higher than taxes and overhead (the former costs are more than half as much as the latter). This was anticipated, as stone is a labour intensive material,

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in contrast to more industrialized materials, such as concrete.

Another interesting observation concerns the location of the project costs. In both projects, the majority of the project costs returns to the local community. In the case of the bridge, a local material (stone) was used with delocalized overhead, whereas in the case of the stone houses, the same material was used in combination with a local engineering office. When the overhead is not local, part of the project cost is diverted outside the local community. Taking into consideration the idea of localization of Moffatt and Kohler [16], the case studies prove that the solution yielding the most significant benefit for a local community is when a local material with on-site know-how is employed. The suitability of a material for a certain project depends on the benefits created for the local economy and the local society, which can be observed in the Sankey diagrams.

With respect to the location of the production of the various materials (Figures 4 and 6), for some products it could be debated whether they should be categorized as local or national. For example, this is the case of the window aluminium frames in Figure 6; the components of the window frames were produced outside Greece and were transported to Nafplion, where was performed the final assembly. In the model, this is represented as a national cost, since only a small percentage of the cost actually is attributed to the local community.

Furthermore, energy and infrastructure costs are in both studies assigned to the national level. Regarding energy costs, this is a reasonable assumption because both the production of electricity and the extraction of the fuel are not taking place in the vicinity of the projects. As regards infrastructure, this is in each case partly local and partly national. For example, here can belong a local office, the company's vehicles and machines as well as investment on software etc. The main part of these costs is not returning to the local community, therefore they have been classified as national. Additionally, the error from not allocating the infrastructure costs is negligible, since these costs (at the project level) amount to a maximum 4% of the total costs of the project in all case studies.

Of course, a full comparison of the two case studies is not possible, because the structures are located in different regions, with different characteristics (network of suppliers, earthquake profile) and serve totally different purposes (a big infrastructure project vs a residential complex).

It should be mentioned that the methodology developed in this paper accounts only for the construction cost of a project but could be also expanded to account for the whole life cycle of a structure, by including the maintenance phase.

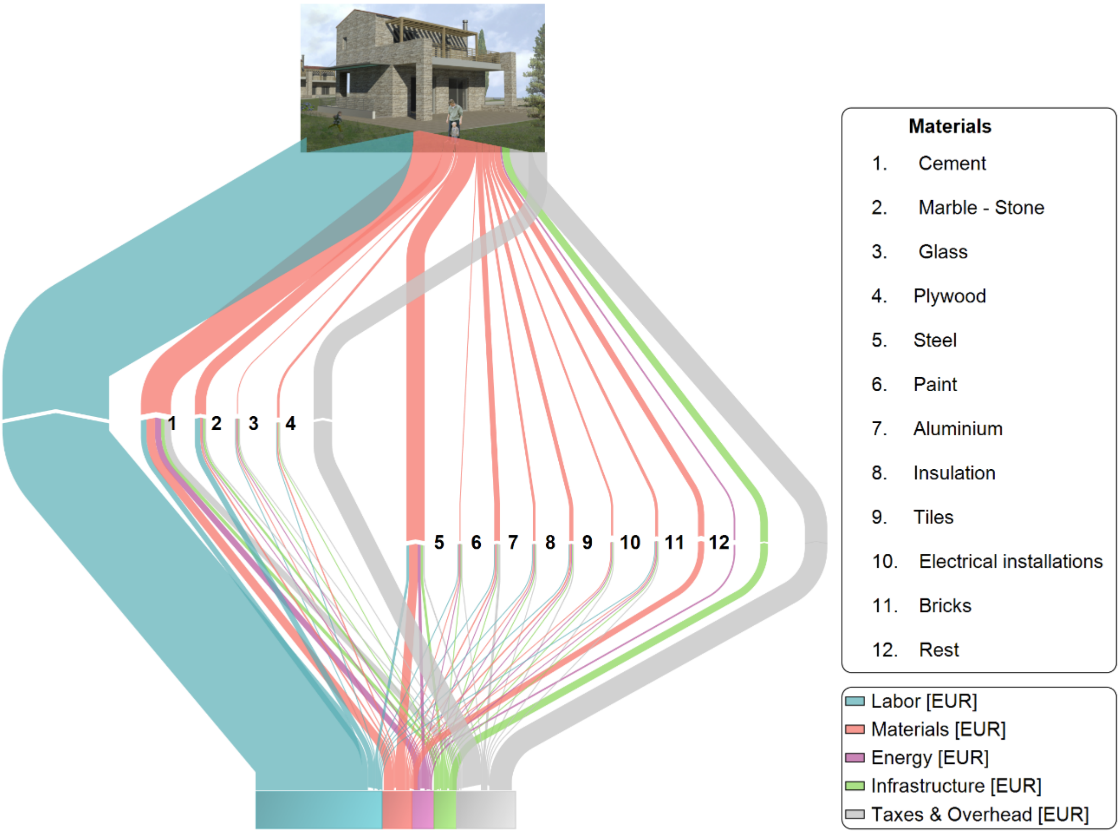

Fig. 6: Economic flow diagram for the construction of the residential stone buildings in Nafplio.

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5 CONCLUSION

This paper presents a new methodology for assessing the economic flows in a project. The aim is to enable a more sustainable decision making that considers the economic transformation of a society as a result of a construction project. In the presented methodology, the cost of a project was divided into five categories and to a local and national level. The material production cost was further broken down by accounting for the cost structure of the manufacturing companies. The cost model of the project was graphically represented by the aid of a Sankey diagram.

The application of the methodology to two case studies led to interesting observations with respect to the benefit of the local communities from a specific project as well as the stakeholder category that has the highest contribution to the total cost. This analysis enables project owners and local authorities to make decisions on the choice of materials and the selection of workmanship/overhead that will reinforce the local economy. An economically sustainable strategy could, for example, lead to a project where the local know-how would be favoured by the choice of a material leading to a better construction design and execution of the project.

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