Economia Aziendale Online

Business and Management Sciences
International Quarterly Review

New Product Development in sustainable mobility: A cost driver analysis perspective in the field of hydrogen-based transportation

Lorenzo Leto, Riccardo Giannetti
Nicola Castellano, Andrea Dello Sbarba

Pavia, September 30, 2025
Volume 16 – N. 3/2025

DOI: 10.13132/2038-5498/16.3.933-952

www.ea2000.it
www.economiaaziendale.it

PaviaUniversityPress

Electronic ISSN 2038-5498
Reg. Trib. Pavia n. 685/2007 R.S.P.

Economia Aziendale Online – Business and Management Sciences International Quarterly Review
Vol. 16-3/2025 - DOI: 10.13132/2038-5498/16.3.933-952

New Product Development in sustainable mobility: a cost driver analysis perspective in the field of hydrogen-based transportation

Lorenzo Leto
PhD. Assegnista
Polo Universitario Sistemi Logistici. Università di Pisa. Italy

Riccardo Giannetti
PhD. Professore Ordinario
Economia Aziendale
Dipartimento di Economia e Management. Università di Pisa. Italy

Nicola Castellano
PhD. Professore Associato
Economia Aziendale
Dipartimento di Economia e Management. Università di Pisa. Italy

Andrea Dello Sbarba
PhD. Professore Associato
Dipartimento di Economia e Management. Università di Pisa. Pisa, Italy

Corresponding Author:

Lorenzo Leto
lorenzo.leto@ pologistica.unipi.it

Cite as:

Leto, L., Giannetti, R., Castellano, N., & Dello Sbarba, A. (2025). New Product Development in sustainable mobility: A cost driver analysis perspective in the field of hydrogen-based transportation. *Economia Aziendale Online*, *16*(2), 933-952.

Section:
Refereed Paper

Received: May 2025
Published: 30/09/2025

ABSTRACT

This study explores the application and effectiveness of cost management techniques, particularly cost driver analysis, in supporting the development and adoption of hydrogen-based transportation solutions, an increasingly relevant field due to environmental concerns. Through a structured literature review of 35 scholarly papers from engineering and management disciplines, we identify prevalent methodologies and significant variations in Total Cost of Ownership (TCO) calculations applied to hydrogen-based vehicles. Our findings reveal relevant cost information that can support the further development of hydrogen vehicles; however, there are considerable inconsistencies in the identification, measurement, and inclusion of key cost drivers, such as infrastructure costs, vehicle configurations, production technology, and institutional factors. The research also points to several critical gaps, including the lack of standardized approaches for TCO estimation, limited attention to the effects of vertical integration, insufficient analysis of interdependencies among cost drivers, and the inadequate consideration of how business model design influences costs. In light of this, the paper provides a normative contribution by proposing a structured map of cost drivers to facilitate improved cost management practices and more reliable economic assessments, supporting both strategic decision-making and policy formulation aimed at enhancing the economic sustainability of hydrogen-based mobility solutions.

Questo studio esplora l'applicazione e l'efficacia delle tecniche di gestione dei costi, in particolare l'analisi dei cost drivers, nel supportare lo sviluppo e l'adozione di soluzioni di trasporto basate sull'idrogeno, un campo sempre più rilevante a causa delle preoccupazioni ambientali. Attraverso una revisione strutturata della letteratura di 35 articoli accademici provenienti da discipline ingegneristiche e gestionali, identifichiamo le metodologie prevalenti e le variazioni significative nei calcoli del Total Cost of Ownership (TCO) applicati ai veicoli basati sull'idrogeno. I nostri risultati rivelano informazioni rilevanti sui costi che possono supportare l'ulteriore sviluppo di veicoli a idrogeno; Tuttavia, ci sono notevoli incongruenze nell'identificazione, nella misurazione e nell'inclusione dei principali fattori di costo, come i costi delle infrastrutture, le configurazioni dei veicoli, la tecnologia di produzione e i fattori istituzionali. La ricerca evidenzia anche diverse lacune critiche, tra cui la mancanza di approcci standardizzati per la stima del TCO, la limitata attenzione agli effetti dell'integrazione verticale, l'analisi insufficiente delle interdipendenze tra i fattori di costo e l'inadeguata considerazione di come la progettazione del modello di business influenzi i costi.

Alla luce di ciò, il paper fornisce un contributo normativo proponendo una mappa strutturata dei driver di costo per facilitare il miglioramento delle pratiche di gestione dei costi e valutazioni economiche più affidabili, supportando sia il processo decisionale strategico che la formulazione di politiche volte a migliorare la sostenibilità economica delle soluzioni di mobilità basate sull'idrogeno.

Keywords: cost driver analysis, total cost of ownership, cost management, hydrogen-based transportation, new product development, sustainable mobility.

1 – Introduction

Growing concern for the environment and the reduction of pollutants is putting increasing pressure on logistics and transportation companies to adapt to this trend by deploying more environmentally friendly vehicles. Hydrogen-based vehicles are currently emerging as a possible solution, mainly due to their potential to drastically reduce greenhouse gas emissions (Ahluwalia *et al*., 2022; Di Vece *et al*., 2022). However, their deployment currently appears to be particularly expensive, especially when compared to more conventional alternatives based on the use of fossil fuels. This is due not only to the high cost of purchasing and producing hydrogen-based vehicles, but also due to the costs associated with the production, storage, and distribution of hydrogen, as well as the development of the necessary refueling infrastructure (Wolff *et al*., 2020; Li & Taghizadeh-Hesary, 2022; Wang *et al*., 2024).

Many researchers emphasize that conducting economic and cost-benefit assessments is essential in developing new products and technologies by allowing companies to evaluate their economic viability and enhance related cost management practices (Magnacca & Giannetti, 2024). Given the need to manage and reduce the costs of hydrogen-based solutions, it can be hypothesized that practices such as cost management and cost driver analysis may support their adoption. However, the application of these approaches in New Product Development (NPD) is inconsistent and can result in outcomes that are not always accurate or comparable. In light of this, this paper aims to explore the application of cost management approaches to support the development and adoption of hydrogen-based mobility. Specifically, it examines how the identification and assessment of cost drivers can support decision-making processes aimed at reaching the economic sustainability of these transportation solutions. To do so, we conducted a structured review of the literature pertaining to the engineering research field that deals with evaluations of the economic feasibility and competitiveness of hydrogen vehicles. Through this literature review, our aim is to assess whether and how cost drivers have been utilized in such a stream of research and discuss the most relevant implications in terms of methodological rigor and accuracy of estimations. The paper intends to provide contributions of normative nature related to the identification of cost drivers, in the introduction of environmentally friendly vehicles, to facilitate their measurement and management. The contributes could be helpful in supporting both research and practical experiments of assessing the economic impacts of hydrogen vehicles, or alternative solutions of sustainable mobility, more in general.

2 – The relevance of cost driver analysis in supporting the development of new technologies and products

Cost management plays a strategic function in the competitive success of organizations, ranging from basic cost calculation methods to sophisticated frameworks that holistically support cost management activities and enhance efficiency across various economic activities (Silvi *et al*., 2004; Anderson, 2006; Kulmala *et al*., 2002). Although there is no universally agreed-upon definition of cost management, it can be considered to consist of a set of practices and techniques aimed at reducing costs while ensuring that the company creates more value for its potential and current customers (Agliata & Tuccillo, 2018; Shank & Govindarajan, 1993). These techniques and practices include, for instance, Target Costing, cost estimation methods, and Value Engineering, which help in managing costs from the initial design phase through to production and beyond (Anderson & Sedatole, 1998; Wouters & Morales, 2014).

While cost management is relevant across various domains, it is deemed particularly essential in strategic processes such as New Product Development (NPD) (Davila & Wouters, 2004), a critical driver of competitive advantage and a key organizational activity for many firms (Chwastyk & Kołosowski, 2014; Christner & Strömsten, 2015).The NPD process fundamentally involves structured, iterative steps aimed at developing profitable and market-responsive products (Davila *et al*., 2009; Gopalakrishnan *et al*., 2015). NPD can take place in diverse contexts, involving a range of products and technologies at varying stages of maturity. Within NPD, cost management approaches can provide essential insights for assessing cost-efficiency, enabling cost reduction through learning, and facilitating financial coordination and negotiation with stakeholders (Magnacca & Giannetti, 2024). These techniques can support NPD by measuring and managing development, production and marketing costs, evaluating investments, and ensuring the financial viability of projects (Pons, 2008).

In other words, integrating cost management approaches into NPD processes can help in: ensuring an efficient development of new products; aligning NPD with market demands; meet NPD financial objectives (Zengin & Ada 2010). In fact, during the design and development phase of new products, important decisions are taken that affect the company's costs (Cooper & Slagmulder, 1999). As example, the future product's configuration, the consequent choice of input materials, the environmental impacts, expected durability, and potential for reuse or disposal are all determined during the design and development stage. Research in NPD has highlighted several significant applications of cost management approaches, including monitoring the effectiveness of strategy implementation, establishing acceptable cost levels for products, identifying and assessing activities and processes in NPD, and adjusting product configurations to optimize the cost-value ratio (Giannetti & Dello Sbarba, 2020). In other words, cost management appears to be a very useful approach for NPD and assessing their economic viability, as furthermore evidenced by numerous studies that employ cost evaluation techniques in this field (e.g., Ally & Prior, 2016; Chwastyk, P., & Kołosowski, 2014; Davila & Wouters, 2004).

Identifying and managing cost drivers—i.e. factors that cause changes and shape the cost structure of an activity or a process—is a key aspect of cost management (Moisello, 2003) and, consequently, of NPD. Cost drivers, which can arise from both managerial choices—such as product design, production complexity, and economies of scale—and external factors like raw material availability and prices, directly shape a firm's sustained costs. Therefore, by understanding how specific activities or events drive costs up or down, firms can better explain cost behavior and identify cost drivers (Banker *et al*., 2018). Understanding and identifying cost drivers is essential to allow their measurement and, when possible, their management, to enhance value creation while achieving cost reductions (Giannetti, 2013; Guardamagna & Moisello, 2008). Despite their importance, research in this area is remarkably sparse. In fact, there is no properly agreed upon definition or taxonomy of cost drivers (Banker and Johnston, 2007). At the same time, the cost driver classifications still used today refer to relatively dated models (e.g., Porter, 1985; Shank & Govindarajan, 1993; Kaplan & Cooper, 1998). Yet, their identification, management, and measurement, while essential, could vary depending on the cost management technique employed to estimate or analyze costs (Agliata & Tuccillo, 2018; Guardamagna & Moisello, 2008). Since our objective is to explore how cost management can enhance NPD through a structured approach to identifying, classifying, and analyzing cost drivers, we will outline the theoretical references employed to achieve our research goal in the methodological section of our study.

3 – The case of hydrogen in transportation sector

One of the causes of air pollution is related to the use of internal combustion engine vehicles (Kiribou *et al*., 2025). To solve this problem, research, governments, industry leaders and society are investigating several environmentally friendly transportation alternatives. Battery electric, hybrid electric, compressed and liquefied natural gas, and hydrogen vehicles appear to be possible viable options (Burke *et al*., 2023; Alonso-Villar *et al*., 2022). In particular, hydrogen has recently gained attention for its potential to reduce greenhouse gas emissions not only in transportation sectors, but also in the power generation and heating (Shardeo & Sarkar, 2024; Hwang *et al*., 2023; Dodds *et al*., 2015). This is because hydrogen combustion is clean since it mostly produces water vapor instead of dangerous contaminants. Nonetheless, there are still obstacles to overcome before it can be widely used in transportation (Ally & Prior, 2016; Wang *et al*., 2024).

First, although hydrogen combustion is generally clean, its production can have varying environmental impacts and costs, at times remaining environmentally harmful while still being more expensive than more polluting alternatives (Palasyuk *et al*., 2005; Lubitz & Tumas, 2007; Li & Taghizadeh-Hesary, 2022). Specifically, there are three main types of hydrogen, depending on the production methods used. These are grey, blue and green hydrogen (von Döllen *et al*., 2021; Chakraborty *et al*., 2022; Hermesmann *et al*., 2022;). Grey hydrogen, the most common and polluting, is generated from fossil fuels without capturing the resulting greenhouse gases, which are released into the atmosphere. Blue hydrogen, on the other hand, involves capturing carbon dioxide (CO2) during production, which mitigates its environmental impact but also raises production costs (Yu *et al*., 2021; Chakraborty *et al*., 2022; Roy & Pramanik, 2024). Finally, green hydrogen, which is often considered as the most environmentally friendly option, is produced through electrolysis powered by renewable energy. However, it remains the most expensive and, therefore, the less economically viable at present (Roy & Pramanik, 2024; Li & Taghizadeh-Hesary, 2022; Ajanovic *et al*., 2021).

In light of this, it is evident that a significant barrier to the widespread adoption of hydrogen as a fuel is its high production and purchase costs, especially for green and blue hydrogen (Parra *et al*., 2019). Recent studies indicate that blue hydrogen could experience substantial cost reductions in the near future, while green hydrogen's cost reductions may take longer and will largely depend on technological advancements (Ueckerdt *et al*., 2021). However, for now, hydrogen remains notably less cost-competitive compared to more polluting alternatives (Roy & Pramanik, 2024).

In addition to the challenges of hydrogen production, there are specific issues associated with its use in transportation. First, hydrogen-based engines remain significantly more expensive than those powered by more traditional fuels (Chen & Wang, 2023; Jones *et al*., 2020).

Second, there are significant issues connected to the lack of hydrogen production infrastructures, the limited number of refueling stations, and the technical challenges of hydrogen storage (Acar & Dincer, 2020; Zhang *et al*., 2019). For example, the availability of refueling stations in European countries remains quite limited, even in those nations where the adoption of hydrogen vehicles is on the rise (European Hydrogen Observatory, 2024). Hydrogen's low energy density per volume requires much more storage space than traditional fossil fuels to hold the same amount of energy (Eftekhari & Fang, 2017). Due to this it is necessary to employ high-pressure tanks to make hydrogen more compact for practical use in vehicles (Zhang *et al*., 2019). In addition, the high flammability of hydrogen raises safety concerns, requiring specialized systems for its storage and transportation (Foorginezhad *et al*., 2021). These safety requirements drive up costs by requiring the use of more expensive materials, components, and processes than those needed for fossil fuel-based solutions.

Another important consideration in the use of hydrogen in transportation is the type of vehicle engine used. Fuel cells appear to be the fastest growing technology today, particularly in the passenger vehicle sector, due to their ability to start at low temperatures and produce low emissions (Anser *et al*., 2025). One alternative solution to fuel cells might be the hydrogen internal combustion engine (Onorati *et al*., 2022). These engines are basically modified versions of conventional internal combustion engines powered by gasoline or diesel. As a result, their use may be advantageous because their manufacturing does not necessitate significant changes in production processes or existing vehicle production infrastructure, and thus does not significantly affect costs (Sari *et al*., 2024). Yet, although hydrogen internal combustion engines do not release CO2, they do produce nitrogen oxides necessitating the use of exhaust treatment technology to reduce and manage these emissions (Boretti, 2020).

Moreover, both hydrogen fuel cell vehicles and hydrogen internal combustion engines may face reliability and maintenance issues. Fuel cells can degrade over time due to factors like poisoning and membrane deterioration (Ren *et al*., 2020; Shabani *et al*., 2019). Hydrogen internal combustion engines may need specific materials and design modifications to accommodate hydrogen's properties, while they can still exhibit reduced durability and reliability compared to conventional engines (Onorati *et al*., 2022; Stępień, 2021).

In summary, the decision to deploy hydrogen-powered vehicles remains complex, particularly with respect to the type of hydrogen to be used, the eventual development of a production and fuel infrastructure, and the engine technology to be used. These decisions are important because they can have a significant impact on both costs and emissions. Yet, accurately calculating the costs and emission reduction benefits associated with hydrogen-based vehicles remains actually challenging (Jones *et al*., 2020; Sadik-Zarda *et al*., 2023; Ahluwalia *et al*., 2022; Sarker & He, 2023).

4 – Research method

Management accounting approaches can support the development of new products and technologies in several different ways (see, for example, Magnacca & Giannetti, 2024). This research is positioned within this specific stream of studies, as it aims to thoroughly explore the application of management accounting techniques in the early stages of technology development, particularly when the technology in question is not yet clearly defined or applied to specific products. This study is positioned within the stream of non-interventionist managerialist research, which seeks to advance academic debates while also providing practitioners and organizations with normative insights to guide decision-making (Malmi, 2016). Within the broader strands of management accounting research, managerialist studies are understood as those in which at least one of the aims is to directly support or facilitate organizational decision-making and control (Malmi, 2016).

More specifically, this study adopts a prescriptive–conceptual approach, as it develops a framework without testing it in practice. The framework is derived from existing contributions and models proposed by other scholars.

As a starting point, we conducted a structured literature review (Hart, 1998) using a systematic and transparent procedure for selecting, coding, and analyzing scholarly work. The review concentrated on studies addressing the implementation of hydrogen technologies in the transport sector and their economic implications, which formed the basis for deriving and organizing the cost-driver elements in our framework.

The objective of this literature review is twofold: (1) firstly, it aims to support the assessments of the economic sustainability of this technology within the transport sector, given that the mobility and transport sectors are among the top five economic sectors with the highest harmful emissions, making it a priority to develop renewable energy solutions in these areas (Triollet *et al*., 2023); (2) secondly, it aims to explore whether and how cost drivers have been considered in the economic analysis mentioned previously. This paper places a strong emphasis on cost drivers, as they can represent a critical variable during the development phase of new technologies, as they play a significant role in guiding strategic decisions, driving cost reduction initiatives, and determining the logic and tools employed to measure the associated costs (Shank & Govindarajan, 1993; Giannetti *et al*., 2016).

To conduct our literature analysis, we collected papers from two different databases: Google Scholar and EBSCO Business Complete. We selected Google Scholar and EBSCO Business Complete because they complement each other in both breadth and disciplinary focus. EBSCO offers strong coverage of peer-reviewed business and management journals, while Google Scholar encompasses a broader range of interdisciplinary and emerging research. Given the interdisciplinary nature of our topic, this combined approach is particularly valuable. We also conducted a brief search in Scopus, but it did not yield additional relevant papers. Nevertheless, since the topic is still emerging, we expect new publications to appear in the near future; future studies may therefore incorporate them and draw on additional databases as appropriate. Finally, since this study is exploratory in nature, we did not apply citation counts as a criterion for inclusion, as our aim was to capture the breadth of perspectives rather than privilege only highly cited contributions. The paper collection process took place during February and March 2025. In particular, we initially conducted our search using the keywords "hydrogen transportation sector" and "total cost of ownership." This search resulted in the identification of 30 papers, selected for their relevance to our focus on hydrogen-based mobility and cost analysis. Although none of these papers were from the management accounting research field, they were chosen because they applied cost management tools, such as Total Cost of Ownership (TCO), alongside other techniques like sensitivity analysis and scenario analysis. However, since these studies were mostly conducted by engineers rather than accountants, they also included technical analyses focused on product development and evaluations of both technical and environmental performance.

To ensure that we had not missed studies that were potentially relevant to us, we expanded our search criteria to include the keywords "*cost calculation*". This strategy allowed us to identify and incorporate five additional studies in our analysis. We also attempted searches using the terms "*hydrogen transportation sector*" along with "*accounting*" and "*management accounting*," but these did not yield relevant results. This made us fully realize the existence of a significant research gap on this topic among management accounting scholars.

Subsequently, we expanded our search strategy by using only the term "*hydrogen transportation sector*." Although this last search did not yield results directly relevant to our analysis, it did help us to identify which aspects are most frequently studied in current research on hydrogen use for mobility (e.g., Shardeo & Sarkar, 2024).

The 35 selected papers were thoroughly reviewed and coded in an Excel spreadsheet to identify their research goals, methodologies, findings, costing techniques, and suggested directions for future research. Following this, we conducted a second level of analysis to identify the cost drivers that are typically acknowledged and discussed. Specifically, we looked at whether these papers only mentioned cost drivers, or whether they also measured them and assessed their impact. We then created a map (Figure 1) that could guide practitioners in identifying cost drivers, assessing their impact, and managing them. From the selected 35 papers, we chose 5 recent studies that represent the main research approaches to cost estimation and provide a comprehensive overview of TCO for hydrogen-based solutions. This selection allows us to identify the most significant costs associated with the deployment of hydrogen solutions in the mobility sector. Identifying these key costs could help practitioners prioritize their cost management and reduction efforts by focusing first on the costs with the greatest impact.

To conduct this analysis, we used the classification of cost drivers developed by Shank & Govindarajan (1993), supplemented by insights from Porter (1985). Porter (1985) proposal of cost drivers categorization needed to be also considered because it allowed us to highlight the influence of certain cost drivers that Shank & Govindarajan (1993) do not address, especially institutional factors, but also interrelationships, location, and time. Institutional factors are critical because regulation, taxation, labor rules, and broader policy frameworks can significantly alter a firm's cost position, often in ways that are beyond managerial control but essential for strategic positioning. Interrelationships across business units are equally relevant, as the sharing of activities, resources, or knowledge among divisions can generate cost advantages through synergies that a purely activity-level or structural/executional perspective may overlook. Location also plays a decisive role, since the geographic configuration of activities affects labor costs, access to inputs, logistics efficiency, and proximity to customers, which in turn shape the total cost structure. The element of time emphasizes how early or late entry, as well as the timing of investments in capacity or technology, influences cost trajectories and competitive advantage, as cost behavior is not static but dynamic across the industry life cycle.

Finally, we also investigated whether any of the reviewed studies considered the impact of the company business model on cost management and behavior, as informed by the work of Giannetti *et al*. (2016). In this view, the business model itself can be regarded as a cost driver, as its design progressively shapes the cost structure (Osterwalder & Pigneur, 2010) and, ultimately, the TCO. The first and most fundamental influence concerns the nature of the offering. Moving from the sale of a physical product to the provision of a mobility service fundamentally alters the underlying cost structure and therefore the TCO and life-cycle costs. Similarly, the adoption of revenue models such as subscription-based or pay-per-use schemes reshapes how revenues are generated and how costs are allocated and shared among stakeholders.

A further influence derives from ownership arrangements. Decisions on whether components or critical infrastructure remain the property of the supplier, are transferred to the customer, or are accessed through leasing or rental agreements determine not only who bears the initial investment but also how operating and replacement costs are distributed over time.

Finally, the business model directs the configuration of relationships across the value network. The degree of cooperation among original equipment manufacturers, suppliers, utilities, and mobility providers affects how resources are combined, how risks are shared, and how expenditures are distributed. Partnerships and interorganizational agreements can reshape the overall cost profile by enabling joint use of assets, shared infrastructures, or collaborative service provision.

In this way, the business model functions as a comprehensive cost driver, shaping costs through its influence on the nature of the offering, revenue logic, ownership arrangements, and interorganizational relationships. This line of reasoning is consistent with strategic frameworks such as the Blue Ocean Strategy (Chan Kim & Mauborgne, 2005), which similarly emphasizes how the re-design of the strategy and the related business model,can fundamentally reshape cost structures, revenue logic, and competitive positioning.

5 – Results

The papers analyzed show a wide variety of approaches used to estimate the costs associated with the introduction of a hydrogen-based mobility solution. In particular, although the TCO approach is by far the most common, its calculation methods vary considerably. First, there is considerable variation in terms of cost items included. For example, while many previous studies (e.g., Gunawan & Monaghan, 2022; Feng & Dong, 2023) include infrastructure costs in the TCO calculation for hydrogen vehicles, the more recent study by Wang *et al*. (2024) excludes these costs due to the underdeveloped state of hydrogen refueling infrastructure and the difficulty of predicting its future development and cost impact. At the same time, Wang *et al*. (2024), unlike many studies (e.g., Ahluwalia *et al*., 2022; Burke *et al*., 2023), considers the effect of subsidies and how they might help reduce capital expenditures. Another example is provided by Morrison *et al*. (2018), who are the only to consider the inconvenience costs associated with the detours that hydrogen vehicles must take to reach the few existing refueling stations in the TCO calculation. Remarkable is the difference in terms of additional assessments. Some studies include an assessment of greenhouse gasses emissions (e.g., Wolff *et al*., 2020; Watabe & Leaver, 2021) compared to other solutions, while others the assessment of the technical performance of vehicles (Ahluwalia *et al*., 2022). There is also no shortage of assessments that take into account different scenarios that can affect the variation of TCO over the years. Several studies (e.g., Jones *et al*., 2020; Wang *et al*., 2024) for example develop sensitivity and scenario analyses to account for different conditions in terms of technology advancements and hydrogen production and refueling infrastructure development, which clearly have in turn a significant effect on costs.

The papers examined also vary significantly in terms of the types of vehicles studied. Some focus on buses (e.g., Ally & Prior, 2016), others on tractors and excavators (e.g., Ahluwalia *et al*., 2022), and still others on trucks (e.g., Alonso-Villar *et al*., 2022). Some even examine standard passenger cars (Morrison *et al*., 2018). However, a common feature across these studies is their comparative approach, where they analyze the TCO of different vehicle technologies. For instance, Jones *et al*. (2020) compare the TCO of battery electric, fuel cell electric, plug-in hybrid electric, and diesel vehicles. Similarly, Muñoz *et al*. (2022) compare the TCO of diesel, natural gas, battery electric, and fuel cell electric city buses.

Our analysis primarily focused on identifying cost drivers in the reviewed papers, relying on Shank & Govindarajan's (1993) framework, integrated with Porter's (1985) cost drivers of time, location, institutional factors, interrelationships, and the business model design as a cost driver based on the contribution by Giannetti *et al*. (2016). The analysis revealed that there are differences in the approaches used to calculate TCO, but also in the extent to which potential cost drivers affecting TCO are considered.

Figure 1 provides a visual representation of the elements that typically constitute TCO in the analyzed papers, as well as a depiction of the cost drivers that can influence the various cost items. In particular, the standard TCO formula (Wouters *et al*., 2005), which shown in the figure, is calculated as the sum of capital expenditures (CAPEX) and operating expenditures (OPEX). CAPEX refers to the upfront, one-time costs required to acquire, build, or implement the vehicle solution—or more generally, any asset, system, or project—such as purchasing the vehicle, infrastructure, or specialized equipment. OPEX, by contrast, represents the recurring costs necessary to operate, maintain, and support the vehicle solution (or asset) throughout its lifecycle, including expenses such as personnel, maintenance, utilities, training, or service subscriptions. The TCO requires adaptation (Messner, 2016) by incorporating both CAPEX and OPEX costs specifically associated with the adoption of hydrogen-based vehicles. We believe that by considering both CAPEX and OPEX, the TCO provides a comprehensive view of the cost impact of a technological solution, ensuring that decisions account not only for the initial investment but also for the long-term costs of operating and sustaining the asset.

In the figure, we use links/arrows to connect each cost driver to the relevant TCO cost items it impacts. The figure also indicates the number of papers that incorporate the effect of each specific cost driver in their TCO calculations, along with the total number of papers that mention the cost driver (shown in parentheses), even if they do not include it in their TCO analysis.

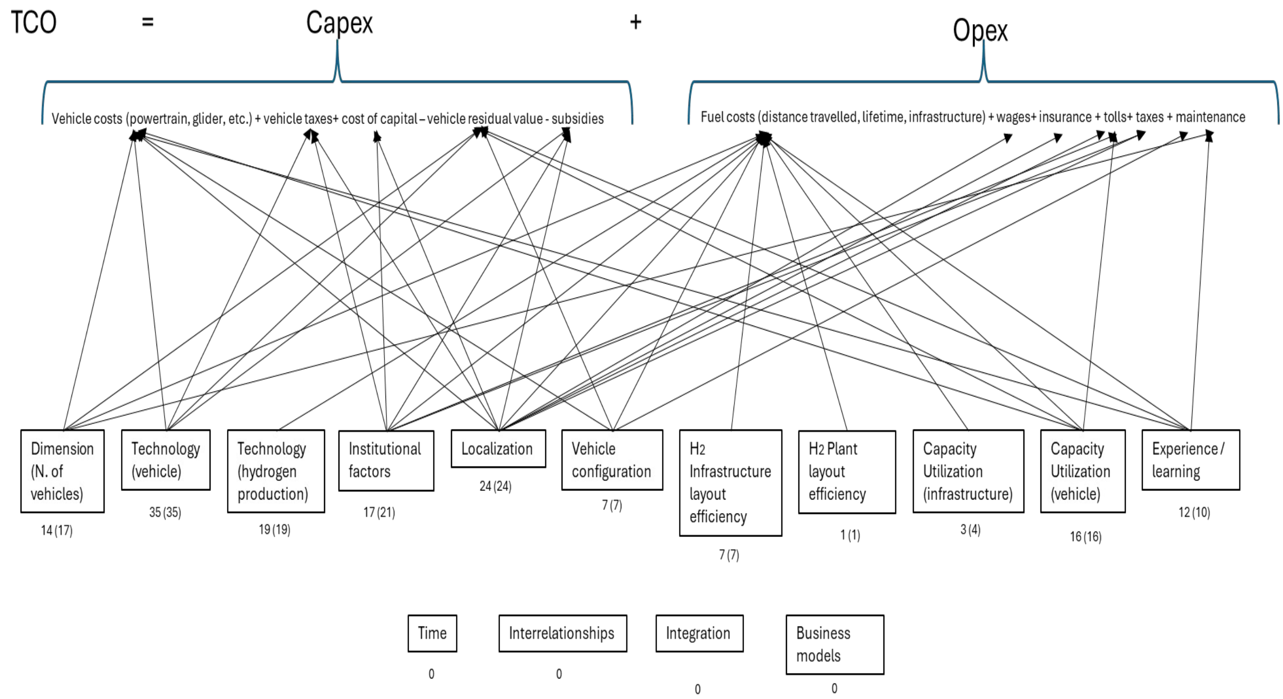

Fig. 1 – Impact of key cost drivers on the TCO of hydrogen vehicles

As the figure shows, the time factor, interrelationships between different business areas, the business model, and the impact of vertical integration (i.e., integration in terms of hydrogen production and/or refueling) are cost drivers not considered in the reviewed papers. In addition, only the paper by Lee *et al*. (2009) considers the impact of different hydrogen plant production layouts on the cost of hydrogen fuel, which affects the overall TCO of hydrogen vehicles. Similarly, only Morrison *et al*. (2018) consider the impact of fueling infrastructure layout on overall TCO noting that an inefficient layout, often due to underdeveloped infrastructure, can increase distance travelled and, therefore, costs.

Regarding hydrogen production, 19 papers examine the cost implications of purchasing hydrogen produced through various technologies (e.g., Barbosa, 2013; Li & Kimura, 2021), such as those based on fossil fuels or renewable energy sources (e.g., blue hydrogen vs. green hydrogen). Only 3 papers explore the impact of fueling station utilization on TCO calculations (e.g., Martin *et al*., 2023), while 16 papers assess the impact of vehicle utilization, considering factors like lifetime (Wang *et al*., 2024), load level (Noll *et al*., 2022), or travel distance (Contestabile, 2011). Additionally, 7 papers focus specifically on the impact of vehicle configuration, particularly engine size (Ahluwalia *et al*., 2022), modularity (Lal *et al*., 2023), and design optimization (Ezzat & Dincer, 2020), aiming to enhance efficiency and performance while reducing overall costs based on company needs.

A common theme in papers involving scenario and sensitivity analysis or TCO projections is the consideration of technological learning and its impact on cost reduction, as well as the impact of scale and economies of scale on both vehicle and hydrogen costs.

Finally, 17 papers consider the influence of institutional factors such as CO2 taxes, tax deductions for low-emission vehicles, or subsidies (e.g., Wang *et al*., 2024). In addition, 24 papers consider the impact of localization, taking into account market conditions, hydrogen production and refueling infrastructure, or regulatory conditions.

As for the rest of our analysis, Table 1 presents the weight percentages of TCO cost items across the five selected studies.

Table 1– Cost item Weights in the TCO of hydrogen vehicles

Paper	Vehicle type	Vehicle/ Acquisition Cost (%)	Propulsion Cost (%)	Storage Cost (%)	Drivetrain Cost (%)	Mainte-nance Cost (%)	Fuel Cost (%)	Insurance Cost (%)	License Cost (%)
Di Vece *et al.* (2022)	City bus	57				22	21		
Ally & Prior (2016)	City bus	49				16	35		
Sarkar & He (2023)	City bus	34				36	40		
Alonso-Villar *et al.* (2022)	Regional trucks	15				3	79	3	<1
Ahluwalia *et al.* (2022)	Excavators	62 (Sum of propulsion, storage and drivetrain)	36	9	17	8	30		

As shown in the table, the weight of the cost items varies considerably. This variation is mainly due to differences between the vehicles studied, as even the bus models examined in the papers are different. However, the differences in costs are so pronounced that they suggest that different market conditions, influenced by regional factors, also play a significant role. In three papers, vehicle acquisition costs are the most significant, while in two others, hydrogen costs are the most significant. In addition, the selected studies show differences in the level of detail of the specific cost items considered. For example, Ahluwalia *et al*. (2022) provide a detailed breakdown of vehicle component costs, such as propulsion, storage, and powertrain. In contrast, Alonso-Villar *et al*. (2022) include insurance and licensing costs, while Sarkar & He (2023) combine maintenance and insurance costs into one item, making it difficult to separate the weight of these two distinct cost items.

6 – Discussion

From our analysis, we identified several critical issues that require attention. First and foremost, the methodologies used to calculate TCO require further examination. The current discrepancies in TCO calculations employed - resulting not only from the different vehicle types and operating environments studied, but also from the different cost items included and the types of supplementary assessments conducted - present significant challenges in comparing results across studies. For this reason, it is essential to establish a shared approach to TCO that enables reliable comparisons both between vehicles of the same type and across different vehicle categories. For example, the study by Ahluwalia *et al*. (2022) exemplifies the importance of assessing the differences in vehicle type and engine power and using the same TCO approach to compare the different options. By analyzing three different vehicle types - tractors, excavators, and wheel loaders - with different horsepower options, the study shows how the dominant cost drivers can shift depending on the vehicle type and engine characteristics. In their study, the fuel costs are the primary cost for hydrogen-based tractors with more than 160 horsepower, while vehicle acquisition costs are the primary cost for hydrogen-based excavators, regardless of horsepower. We believe that recognizing these differences might guide companies in identifying and managing cost drivers when adopting hydrogen-based technologies for mobility. By assessing the most significant costs and their impact and manageability, companies can make informed decisions about which hydrogen-based vehicles are more economically viable. Moreover, the variability in cost item weights across vehicle types suggests that some hydrogen-based vehicles are currently more competitive, offering more opportunities to value their adoption and manage their costs (Ahluwalia *et al*., 2022).

Beyond issues related to TCO calculations, we emphasize that substantial variation arises from the cost drivers considered, which not only affects the consistency and comparability of TCO results but also shapes the effectiveness of cost management decisions. In the absence of a standardized framework for identifying cost drivers, researchers exercise considerable discretion in their selection, thereby increasing conceptual ambiguity and complicating meaningful comparisons across studies and vehicle technologies.

We argue that the cost driver framework presented in the results section (Figure 1) provides a foundation for systematically identifying and managing cost drivers, thereby contributing to a more standardized approach to TCO calculation that can support both researchers and practitioners.

Finally, our analysis reveals that several critical cost drivers remain largely neglected in current research—notably interrelationships, time, integration and business models. Interrelationships, in particular, are important because they highlight how activities within and across value chains, as well as between business units within the same organization, influence one another. Cost savings or efficiencies in one area may depend on, or generate, additional costs in another, meaning that overlooking these linkages can lead to an incomplete or misleading assessment of total costs. Interrelationships can play an important role also in the case of mergers and acquisitions, where complementarities between firms generate synergies and economies of scope that enhance innovative performance (see for example, Orame and Pianeselli, 2023). Time is equally important, as costs often unfold dynamically over the lifecycle of a product or system (Porter, 1985). Delays, accelerated schedules, or long-term maintenance requirements can substantially alter TCO, underscoring the need to capture temporal dimensions in cost analyses. Vertical integration is another critical factor, as the degree to which firms internalize activities along the value chain affects both cost structures and flexibility (Huth, Wittek, & Spengler, 2013). While higher integration can reduce transaction costs and strengthen coordination, it may also increase fixed costs and reduce adaptability, making its role in TCO highly context-dependent. The business model is equally important, as it defines the nature of the offering, the revenue logic, and the ownership arrangements that shape how costs are generated, allocated, and shared among stakeholders (Osterwalder & Pigneur, 2010; Giannetti *et al*., 2016). Different business model designs can fundamentally alter cost behavior and, ultimately, the TCO.

7 – Conclusions and future research

This study has examined the role of cost management techniques—particularly cost driver analysis—in supporting the economic assessment and adoption of hydrogen-based transportation solutions. Drawing on a structured literature review of 35 scholarly papers across engineering and management disciplines, it has identified how TCO is currently applied to hydrogen vehicles, revealed major discrepancies in its calculation, and highlighted critical cost drivers that shape economic viability.

The paper makes three main contributions. First, it advances knowledge by systematically documenting the heterogeneity of TCO methodologies, showing how differences in vehicle types, operating contexts, the inclusion of specific cost items and drivers, as well as supplementary assessments, hinder comparability across studies. Second, it provides a normative contribution by developing a structured cost driver framework (Figure 1), which offers a shared basis for identifying, assessing, and managing cost drivers, thereby enabling more reliable and consistent TCO calculations. Third, it extends existing research by identifying critical cost drivers that are largely overlooked—such as interrelationships, temporal dynamics, integration, and business models—and demonstrating how their omission can lead to incomplete or misleading cost assessments.

Taken together, these contributions highlight, from a management accounting perspective, the urgency of mitigating methodological inconsistencies and moving toward a standardized TCO approach that can better guide decision-making for hydrogen-based and other sustainable mobility solutions. To address the inconsistencies in TCO calculations, future research should focus on developing a standardized methodology that ensures comparability across studies and practical applicability for decision-makers. This requires establishing also clear guidelines on cost driver selection, calculation methods, and data sources to minimize discrepancies. Additionally, including industry-specific adaptations and specific regulatory frameworks could support the adoption of a more consistent approach, ultimately enhancing the reliability of TCO assessments for hydrogen-based and other sustainable mobility solutions.

We believe that a better understanding of the cost behavior (Banker *et al*., 2018) of hydrogen-based vehicle can actually not only help companies, particularly logistics ones, choose the best vehicle option for their needs but also support vehicle manufacturers to prioritize their cost management strategies. Identifying the most impactful costs and cost drivers can facilitate targeted efforts by vehicle manufacturers to reduce expenses associated with production processes and components that have the greatest influence on TCO. This approach can also be valuable for policymakers, who can design interventions that address the most significant cost-related barriers facing the industry.

For example, if vehicle acquisition costs are prohibitive, subsidies may be a viable policy tool. Conversely, if hydrogen fuel costs are the primary barrier, policymakers might consider tax incentives for hydrogen fuel or increased taxes on polluting fuels. If infrastructure costs are the major issue, incentives to expand refueling stations or hydrogen production facilities may be needed.

The map in Figure 1, presented in the results section, which links cost drivers to the costs they influence, can serve as a valuable tool for identifying relevant cost drivers and evaluating potential management strategies, tailored to the areas of influence specific to different users, whether they are policymakers, logistics companies, or other stakeholders. In other words, this approach can be used to identify cost drivers, although their degree of manageability will depend on the subject using it. We believe that this approach can contribute to the field of practice and, in general, to the efforts aimed at facilitating the introduction of hydrogen-based vehicles by managing and reducing their costs.

We also suggest that future research should examine the interdependencies among cost drivers. Our prescriptive map does not capture these relationships, yet an intervention in one driver may have cascading effects on others. Understanding these dynamics could help prioritize interventions that generate wider positive impacts, thereby enhancing overall cost management strategies in hydrogen mobility.

Finally, given that the reviewed papers address different vehicle categories, future research should replicate the proposed framework across diverse vehicle types to examine how product configuration shapes the relevance and management of cost drivers. Such an extension would enable a more granular analysis of the "vehicle configuration" driver, highlighting differences across segments and identifying targeted cost-reduction strategies—for example, comparing approaches to lowering the TCO of personal mobility solutions versus urban or regional transport.

We suggest that the lack of studies addressing certain drivers seems to stem from the engineering orientation of much of the existing literature, which focuses on technological and production aspects while overlooking strategic and organizational dimensions. Yet, from a strategic management perspective, a differentiation strategy—for example, adopting a fully green or hydrogen-based fleet—may involve higher costs to deliver a premium offering (e.g., sustainable and green mobility), thereby justifying a premium price aimed at specific customer segments.

Addressing this gap from a more holistic, strategic, and management-accounting perspective would be especially valuable in light also of current industry practices. Metterei una nota e il giallo in nota. Firms such as BYD and Tesla currently pursue distinct integration strategies and development timelines in electric mobility, offering promising cases for comparative analysis (Masiero *et al*., 2016; Moritz *et al*., 2015).

8 – Funding

This study is financed by the ***European Union—NextGenerationEU*** (*National Sustainable Mobility Center CN00000023, Italian Ministry of University and Research Decree n. 1033—17/06/2022, Spoke 10*) and by Polo Sistemi Logistici Livorno (*Logistics systems hub of Leghorn*) of the University of Pisa.

9 – References

Acar, C., & Dincer, I. (2020). The potential role of hydrogen as a sustainable transportation fuel to combat global warming. *International Journal of Hydrogen Energy*, 45(5), 3396-3406. DOI: https://doi.org/10.1016/j.ijhydene.2018.10.149

Agliata, F., & Tuccillo, D. (2018). La contabilità dei costi quale strumento di supporto decisionale nell'erogazione dei pubblici servizi [Cost accounting as a decision support tool in the provision of public services]. *Economia Aziendale Online*, *9*(2). DOI: 10.13132/2038-5498/9.2.115-126

Ahluwalia, R. K., Wang, X., Star, A. G., & Papadias, D. D. (2022). Performance and cost of fuel cells for off-road heavy-duty vehicles. *International Journal of Hydrogen Energy*, 47(20), 10990-11006. DOI: https://doi.org/10.1016/j.ijhydene.2022.01.144

Ajanovic, A., Glatt, A., & Haas, R. (2021). Prospects and impediments for hydrogen fuel cell buses. *Energy*, 235, 121340. DOI: https://doi.org/10.1016/j.energy.2021.121340

Ajanovic, A., Sayer, M., & Haas, R. (2022). The economics and the environmental benignity of different colors of hydrogen. *International Journal of Hydrogen Energy*, *47*(57), 24136-24154. DOI: https://doi.org/10.1016/j.ijhydene.2022.02.094

Ally, J., & Pryor, T. (2016). Life cycle costing of diesel, natural gas, hybrid and hydrogen fuel cell bus systems: An Australian case study. *Energy Policy*, 94, 285-294. DOI: https://doi.org/10.1016/j.enpol.2016.03.039

Alonso-Villar, A., Davíðsdóttir, B., Stefánsson, H., Ásgeirsson, E. I., & Kristjánsson, R. (2022). Technical, economic, and environmental feasibility of alternative fuel heavy-duty vehicles in Iceland. *Journal of Cleaner Production*, 369, 133249. DOI: https://doi.org/10.1016/j.jclepro.2022.133249

Anderson, S. W. (2006). Managing costs and cost structure throughout the value chain: research on strategic cost management. *Handbooks of Management Accounting Research*, *2*, 481-506.

Anderson, S. W., & Sedatole, K. (1998). Designing quality into products: The use of accounting data in new product development. *Accounting Horizons*, 12(3), 213.

Anser, M. K., Ali, S., Umair, M., Javid, R., & Tayab, M. (2025). Optimizing hydrogen integration in vehicle fuel systems for sustainable development: a step towards economic decarbonization. *International Journal of Hydrogen Energy*, *98*, 321-333. DOI: https://doi.org/10.1016/j.ijhydene.2024.12.009

Azzone, G., & Noci, G. (1996). Measuring the environmental performance of new products: an integrated approach. *International Journal of Production Research*, 34(11), 3055-3078. DOI: https://doi.org/10.1080/00207549608905077

Banker, R. D., Byzalov, D., Fang, S., & Liang, Y. (2018). Cost management research. *Journal of Management Accounting Research*, *30*(3), 187-209. DOI: http://dx.doi.org/10.2139/ssrn.2882713

Banker, R.D. & Johnston, H.H. (2007) Cost and profit driver research, in Chapman, C.S., Hopwood, A.G. and Shields, M.D. (Eds), *Handbook of Management Accounting Research*, Vol. 2, Elsevier, Oxford, pp. 531-556.

Barbosa, F. C. (2013). Hydrogen fuel cell transit bus technology into a technical-economical perspective (No. 2013-36-0270). *SAE Technical Paper*. DOI: https://doi.org/10.4271/2013-36-0270

Booker, D. M., Drake, A. R., & Heitger, D. L. (2007). New product development: How cost information precision affects designer focus and behavior in a multiple objective setting. *Behavioral Research in Accounting*, *19*(1), 19-41. DOI: https://doi.org/10.2308/bria.2007.19.1.19

Boretti, A. (2020). Hydrogen internal combustion engines to 2030. *International Journal of Hydrogen Energy*, *45*(43), 23692-23703. DOI: https://doi.org/10.1016/j.ijhydene.2020.06.022

Burke, A. F., Zhao, J., Miller, M. R., Sinha, A., & Fulton, L. M. (2023). Projections of the costs of medium- and heavy-duty battery-electric and fuel cell vehicles (2020-2040) and related economic issues. *Energy for Sustainable Development*, 77, 101343. DOI: https://doi.org/10.1016/j.esd.2023.101343

Chakraborty, S., Dash, S. K., Elavarasan, R. M., Kaur, A., Elangovan, D., Meraj, S. T., ... & Said, Z. (2022). Hydrogen energy as future of sustainable mobility. *Frontiers in Energy Research*, 10, 893475. DOI: yhttps://doi.org/10.3389/fenrg.2022.893475

Chan Kim, W., & Mauborgne, R. A. (2005). *Blue ocean strategy*. Harvard Business Review Press.

Chen, Z., & Wang, H. (2023). Total Cost of Ownership Analysis of Fuel Cell Electric Bus with Different Hydrogen Supply Alternatives. *Sustainability*, 16(1), 259. DOI: https://doi.org/10.3390/su16010259

Christner, C. H., & Strömsten, T. (2015). Scientists, venture capitalists and the stock exchange: The mediating role of accounting in product innovation. *Management Accounting Research*, *28*, 50-67. DOI: https://doi.org/10.1016/j.mar.2015.04.004

Chwastyk, P., & Kołosowski, M. (2014). Estimating the cost of the new product in development process. *Procedia Engineering*, *69*, 351-360. DOI: https://doi.org/10.1016/j.proeng.2014.02.243

Contestabile, M., Offer, G. J., Slade, R., Jaeger, F., & Thoennes, M. (2011). Battery electric vehicles, hydrogen fuel cells and biofuels. Which will be the winner?. *Energy & Environmental Science*, 4(10), 3754-3772. DOI:10.1039/C1EE01804C

Cooper, R., & Slagmulder, R. (1999). Develop profitable new products with target costing. *MIT Sloan Management Review*.

Coppitters, D., Verleysen, K., De Paepe, W., & Contino, F. (2022). How can renewable hydrogen compete with diesel in public transport? Robust design optimization of a hydrogen refueling station under techno-economic and environmental uncertainty. *Applied Energy*, 312, 118694. DOI: https://doi.org/10.1016/j.apenergy.2022.118694

Davila, T. (2000). An empirical study on the drivers of management control systems' design in new product development. *Accounting, organizations and society*, *25*(4-5), 383-409. DOI: https://doi.org/10.1016/S0361-3682(99)00034-3

Davila, A., Foster, G., & Li, M. (2009). Reasons for management control systems adoption: Insights from product development systems choice by early-stage entrepreneurial companies. *Accounting, Organizations and Society*, *34*(3-4), 322-347. DOI: https://doi.org/10.1016/j.aos.2008.08.002

Davila, A., & Wouters, M. (2004). Designing cost-competitive technology products through cost management. *Accounting horizons*, *18*(1), 13-26. DOI: https://doi.org/10.2308/acch.2004.18.1.13

Di Vece, G., Di Nunno, D., Bilancia, M., & Verdino, V. (2022). Development of a total cost of ownership model to compare BEVs, FCEVs and diesel powertrains on bus applications (No. 2022-37-0030). *SAE Technical Paper*. DOI: https://doi.org/10.4271/2022-37-0030

Dodds, P. E., Staffell, I., Hawkes, A. D., Li, F., Grünewald, P., McDowall, W., & Ekins, P. (2015). Hydrogen and fuel cell technologies for heating: A review. *International journal of hydrogen energy*, *40*(5), 2065-2083. DOI: https://doi.org/10.1016/j.ijhydene.2014.11.059

Eftekhari, A., & Fang, B. (2017). Electrochemical hydrogen storage: opportunities for fuel storage, batteries, fuel cells, and supercapacitors. *International Journal of Hydrogen Energy*, *42*(40), 25143-25165. DOI: https://doi.org/10.1016/j.ijhydene.2017.08.103

Ezzat, M., & Dincer, I. (2020). Exergoeconomic analysis and optimization of a new hybrid fuel cell vehicle. *International Journal of Hydrogen Energy*, 45(9), 5734-5744. DOI: https://doi.org/10.1016/j.ijhydene.2019.07.104

Feng, Y., & Dong, Z. (2023). Comparative lifecycle costs and emissions of electrified powertrains for light-duty logistics trucks. *Transportation Research Part D: Transport and Environment*, 117, 103672. DOI: https://doi.org/10.1016/j.trd.2023.103672

Feeney, O., & Pierce, B. (2016). Strong structuration theory and accounting information: an empirical study. *Accounting, auditing & accountability journal*, *29*(7), 1152-1176. DOI: https://doi.org/10.1108/AAAJ-07-2015-2130

Feeney, O., & Pierce, B. (2018). Accounting and new product development: The importance of interactions within social and technical structures. *Qualitative Research in Accounting & Management*, *15*(2), 251-279. DOI: https://doi.org/10.1108/QRAM-05-2017-0045

Foorginezhad, S., Mohseni-Dargah, M., Falahati, Z., Abbassi, R., Razmjou, A., & Asadnia, M. (2021). Sensing advancement towards safety assessment of hydrogen fuel cell vehicles. *Journal of Power Sources*, *489*, 229450. DOI: https://doi.org/10.1016/j.jpowsour.2021.229450

Giannetti, R. (2013). *La riduzione strategica dei costi: La gestione dei cost driver per business model economicamente sostenibili* [Strategic cost reduction: Managing cost drivers for economically sustainable business models] (Vol. 34). G. Giappichelli Editore.

Giannetti, R., & Dello Sbarba, A. (2020). Analisi e gestione dei cost driver nello sviluppo nuovi prodotti: Il caso Resolve [Analysis and management of cost drivers in new product development: The Resolve case]. In *Analisi, misurazione e gestione dei costi. Contesti e approcci emergenti nello studio dei costi* [Analysis, measurement and management of costs: Contexts and emerging approaches in cost study] (Vol. 10388). FrancoAngeli.

Giannetti, R., Risso, L., & Cinquini, L. (2016). Managing costs by business model: issues emerging from the case of E-Car. *Measuring Business Excellence*, *20*(4), 28-45. DOI: https://doi.org/10.1108/MBE-08-2016-0039

Gopalakrishnan, M., Libby, T., Samuels, J. A., & Swenson, D. (2015). The effect of cost goal specificity and new product development process on cost reduction performance. *Accounting, Organizations and Society*, *42*, 1-11. DOI: https://doi.org/10.1016/j.aos.2015.01.003

Gray, N., O'Shea, R., Wall, D., Smyth, B., Lens, P. N., & Murphy, J. D. (2022). Batteries, fuel cells, or engines? A probabilistic economic and environmental assessment of electricity and electrofuels for heavy goods vehicles. *Advances in Applied Energy*, 8, 100110. DOI: https://doi.org/10.1016/j.adapen.2022.100110

Guardamagna, L., & Moisello, A. M. (2008). *Riflessioni sul modello di ottimizzazione dei cost driver di Babad e Balachandran* [Reflections on Babad and Balachandran's cost driver optimization model]. *Economia Aziendale Online*, *1*(5), 95–124. DOI: http://dx.doi.org/10.4485/ea2038-5498.95-124

Gunawan, T. A., & Monaghan, R. F. (2022). Techno-econo-environmental comparisons of zero-and low-emission heavy-duty trucks. *Applied Energy*, 308, 118327. DOI: https://doi.org/10.1016/j.apenergy.2021.118327

Hao, X., Ou, S., Lin, Z., He, X., Bouchard, J., Wang, H., & Li, L. (2022). Evaluating the current perceived cost of ownership for buses and trucks in China. *Energy*, *254*, 124383. DOI: https://doi.org/10.1016/j.energy.2022.124383

Hart, C. (1998). *Doing a Literature Review: Releasing the Social Science Research Imagination*. London: Sage.

Hermesmann, M., & Müller, T. E. (2022). Green, turquoise, blue, or grey? Environmentally friendly hydrogen production in transforming energy systems. *Progress in Energy and Combustion Science*, *90*, 100996. DOI: https://doi.org/10.1016/j.pecs.2022.100996

Hopwood, A. G., Burchell, S., & Clubb, C. (1979). The development of accounting in its international context: past concerns and emergent issues. *An Historical and Contemporary Review of the Development of International Accounting*.

Huth, C., Wittek, K., & Spengler, T. S. (2013). OEM strategies for vertical integration in the battery value chain. *International Journal of Automotive Technology and Management*, *13*(1), 75-92. DOI: https://doi.org/10.1504/IJATM.2013.052780

Hwang, J., Maharjan, K., & Cho, H. (2023). A review of hydrogen utilization in power generation and transportation sectors: Achievements and future challenges. *International journal of hydrogen energy*. DOI: https://doi.org/10.1016/j.ijhydene.2023.04.024

Ishimoto, Y., Wulf, C., Schonhoff, A., & Kuckshinrichs, W. (2024). Life cycle costing approaches of fuel cell and hydrogen systems: A literature review. *International journal of hydrogen energy*, *54*, 361-374. DOI: https://doi.org/10.1016/j.ijhydene.2023.04.035

Janssen, S., Moeller, K., & Schlaefke, M. (2011). Using performance measures conceptually in innovation control. *Journal of Management Control*, *22*, 107-128. DOI: 10.1007/s00187-011-0130-y

Jones, J., Genovese, A., & Tob-Ogu, A. (2020). Hydrogen vehicles in urban logistics: A total cost of ownership analysis and some policy implications. *Renewable and Sustainable Energy Reviews*, 119, 109595. DOI: https://doi.org/10.1016/j.rser.2019.109595

Kaplan, R. S., & Cooper, R. (1998). *Cost & effect: using integrated cost systems to drive profitability and performance*. Harvard Business Press.

Kiribou, I. A. R., Neya, T., Nana, B., Ogunjobi, K., Daho, T., Muema, F. M., & Sintayehu, D. W. (2025). Road Transport and Urban Mobility Greenhouse Gas Emissions Factor for Air Pollution Modeling in Burkina Faso. *Journal of Urban Mobility*, *7*, 100106. DOI: https://doi.org/10.1016/j.urbmob.2025.100106

Kulmala, H. I., Paranko, J., & Uusi-Rauva, E. (2002). The role of cost management in network relationships. *International Journal of Production Economics*, *79*(1), 33-43. DOI: https://doi.org/10.1016/S0925-5273(00)00061-X

Lal, A., Renaldy, T., Breuning, L., Hamacher, T., & You, F. (2023). Electrifying light commercial vehicles for last-mile deliveries: Environmental and economic perspectives. *Journal of Cleaner Production*, 416, 137933. DOI: https://doi.org/10.1016/j.jclepro.2023.137933

Lee, J. Y., Yoo, M., Cha, K., Lim, T. W., & Hur, T. (2009). Life cycle cost analysis to examine the economical feasibility of hydrogen as an alternative fuel. *International Journal of Hydrogen Energy*, *34*(10), 4243-4255. DOI: https://doi.org/10.1016/j.ijhydene.2009.03.012

Li, Y., & Kimura, S. (2021). Economic competitiveness and environmental implications of hydrogen energy and fuel cell electric vehicles in ASEAN countries: The current and future scenarios. *Energy Policy*, 148, 111980. DOI: https://doi.org/10.1016/j.enpol.2020.111980

Li, L., Liu, Z., Deng, C., Xie, N., Ren, J., Sun, Y., ... & Yang, S. (2022). Thermodynamic and exergoeconomic analyses of a vehicular fuel cell power system with waste heat recovery for cabin heating and reactants preheating. *Energy*, 247, 123465. DOI: https://doi.org/10.1016/j.energy.2022.123465

Li, Y., & Taghizadeh-Hesary, F. (2022). The economic feasibility of green hydrogen and fuel cell electric vehicles for road transport in China. *Energy Policy*, 160, 112703. DOI: https://doi.org/10.1016/j.enpol.2021.112703

Lubitz, W., & Tumas, W. (2007). Hydrogen: an overview. *Chemical reviews*, *107*(10), 3900-3903. DOI: 10.1021/cr050200z

Magnacca, F., & Giannetti, R. (2024). Management accounting and new product development: a systematic literature review and future research directions. *Journal of Management and Governance*, 28(2), 651-685. DOI: https://doi.org/10.1007/s10997-022-09650-9

Malmi, T. (2016). Managerialist studies in management accounting: 1990–2014. *Management Accounting Research*, *31*, 31-44. DOI: https://doi.org/10.1016/j.mar.2016.02.002

Martin, J., Neumann, A., & Ødegård, A. (2023). Renewable hydrogen and synthetic fuels versus fossil fuels for trucking, shipping and aviation: A holistic cost model. *Renewable and Sustainable Energy Reviews*, 186, 113637. DOI: https://doi.org/10.1016/j.rser.2023.113637

Masiero, G., Ogasavara, M. H., Jussani, A. C., & Risso, M. L. (2016). Electric vehicles in China: BYD strategies and government subsidies. *RAI Revista de Administração e Inovação*, *13*(1), 3-11. DOI: https://doi.org/10.1016/j.rai.2016.01.001

Mert, S. O., Dincer, I., & Ozcelik, Z. (2007). Exergoeconomic analysis of a vehicular PEM fuel cell system. *Journal of Power Sources*, 165(1), 244-252. DOI: https://doi.org/10.1016/j.jpowsour.2006.12.002

Messner, M. (2016). Does industry matter? How industry context shapes management accounting practice. *Management Accounting Research*, *31*, 103-111.

Mio, A., Barbera, E., Pavan, A. M., Danielis, R., Bertucco, A., & Fermeglia, M. (2023). Analysis of the energetic, economic, and environmental performance of hydrogen utilization for port logistic activities. *Applied Energy*, 347, 121431 DOI: https://doi.org/10.1016/j.apenergy.2023.121431

Moisello, A. (2003). ABC & EVA: un'integrazione possibile. La valutazione del costo di prodotto nell'ottica della creazione di valore [ABC & EVA: A possible integration. Product cost assessment from the perspective of value creation]. *Economia Aziendale Online*, *(1)*, 25–40. DOI: http://dx.doi.org/10.4485/ea2038-5498.25-40

Moon, S., Lee, Y. J., & Lee, D. J. (2022). A cost-effectiveness analysis of fuel cell electric vehicles considering infrastructure costs and greenhouse gas emissions: An empirical case study in Korea. *Sustainable Energy Technologies and Assessments*, 54, 102777. DOI: https://doi.org/10.1016/j.seta.2022.102777

Morrison, G., Stevens, J., & Joseck, F. (2018). Relative economic competitiveness of light-duty battery electric and fuel cell electric vehicles. *Transportation Research Part C: Emerging Technologies*, 87, 183-196. DOI: https://doi.org/10.1016/j.trc.2018.01.005

Moritz, M., Redlich, T., Krenz, P., Buxbaum-Conradi, S., & Wulfsberg, J. P. (2015, August). Tesla Motors, Inc.: Pioneer towards a new strategic approach in the automobile industry along the open source movement?. In *2015 Portland International Conference On Management Of Engineering And Technology (picmet)* (pp. 85-92). IEEE. DOI: 10.1109/PICMET.2015.7273032

Mouritsen, J., Hansen, A., & Hansen, C. Ø. (2009). Short and long translations: Management accounting calculations and innovation management. *Accounting, Organizations and Society*, *34*(6-7), 738-754. DOI: https://doi.org/10.1016/j.aos.2009.01.006

Muñoz, P., Franceschini, E. A., Levitan, D., Rodriguez, C. R., Humana, T., & Perelmuter, G. C. (2022). Comparative analysis of cost, emissions and fuel consumption of diesel, natural gas, electric and hydrogen urban buses. *Energy Conversion and Management*, 257, 115412. DOI: https://doi.org/10.1016/j.enconman.2022.115412

Nixon, B. (1998). Research and development performance measurement: a case study. *Management accounting research*, 9(3), 329-355. DOI: https://doi.org/10.1006/mare.1998.0079

Noll, B., del Val, S., Schmidt, T. S., & Steffen, B. (2022). Analyzing the competitiveness of low-carbon drive-technologies in road-freight: A total cost of ownership analysis in Europe. *Applied Energy*, 306, 118079. DOI: https://doi.org/10.1016/j.apenergy.2021.118079

Onorati, A., Payri, R., Vaglieco, B. M., Agarwal, A. K., Bae, C., Bruneaux, G., ... & Zhao, H. (2022). The role of hydrogen for future internal combustion engines. *International Journal of Engine Research*, 23(4), 529-540. DOI: https://doi.org/10.1177/14680874221081947

Osterwalder, A. and Pigneur, Y. (2010) Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. Wiley, New Jersey.

Palasyuk, T., Tkacz, M., & Vajda, P. (2005). High pressure studies of the erbium–hydrogen system. *Solid state communications*, *135*(4), 226-231. DOI: https://doi.org/10.1016/j.ssc.2005.04.038

Pianeselli, D., & Orame, A. (2023). Thinking the green transition: evidence from the automotive industry. *Bank of Italy Occasional Paper*, (767). DOI: http://dx.doi.org/10.2139/ssrn.4464198

Pons, D. (2008). Project management for new product development. *Project management journal*, *39*(2), 82-97.

Porter, M. E. (1985). *The Competitive Advantage: Creating and Sustaining Superior Performance*. NY: Free Press.

Rout, C., Li, H., Dupont, V., & Wadud, Z. (2022). A comparative total cost of ownership analysis of heavy duty on-road and off-road vehicles powered by hydrogen, electricity, and diesel. *Heliyon*, 8(12). DOI: https://doi.org/10.1016/j.heliyon.2022.e12417

Roy, A., & Pramanik, S. (2024). A review of the hydrogen fuel path to emission reduction in the surface transport industry. *International Journal of Hydrogen Energy*, 49(D), 792-821. DOI: https://doi.org/10.1016/j.ijhydene.2023.07.010

Sadik-Zada, E. R., Gonzalez, E. D. S., Gatto, A., Althaus, T., & Quliyev, F. (2023). Pathways to the hydrogen mobility futures in German public transportation: A scenario analysis. *Renewable Energy*, 205, 384-392. DOI: https://doi.org/10.1016/j.renene.2022.12.087

Sari, R., Shah, A., Kumar, P., Cleary, D., Rairikar, S., Sonawane, S. B., & Thipse, S. S. (2024). Hydrogen Internal Combustion Engine Strategies for Heavy-Duty Transportation: Engine and System Level Perspective. *SAE Technical Papers*. DOI: https://doi.org/10.4271/2024-26-0175.

Sarkar, S., & He, X. (2023). Techno-Economic Assessment of Future Fuels and Vehicle Technologies: Fuel Cell, Batteries, and Natural Gas Prospects in India (No. 2023-01-0234). *SAE Technical Paper*. DOI: https://doi.org/10.4271/2023-01-0234

Sayadi, S., Tsatsaronis, G., & Duelk, C. (2014). Exergoeconomic analysis of vehicular PEM (proton exchange membrane) fuel cell systems with and without expander. *Energy*, 77, 608-622. DOI: https://doi.org/10.1016/j.energy.2014.09.054

Shabani, B., Hafttananian, M., Khamani, S., Ramiar, A., & Ranjbar, A. A. (2019). Poisoning of proton exchange membrane fuel cells by contaminants and impurities: Review of mechanisms, effects, and mitigation strategies. *Journal of Power Sources*, *427*, 21-48. DOI: https://doi.org/10.1016/j.jpowsour.2019.03.097

Shank, J. K., & Govindarajan V.. (1993). *Strategic Cost Management: The New Tool for Competitive Advantage*. New York: Free Press.

Shardeo, V., & Sarkar, B. D. (2024). Adoption of hydrogen-fueled freight transportation: A strategy toward sustainability. *Business Strategy and the Environment*, *33*(2), 223-240. DOI: https://doi.org/10.1002/bse.3482

Silvi, R. (2004). Knowledge management: a strategic cost management perspective. *Economia Aziendale Online-*, (1), 1-26. DOI: http://dx.doi.org/10.13132/2038-5498/2004.1.1-26

Sontakke, U. R., Jaju, S., & Mahajan, D. K. (2024). Total cost of ownership analysis of fuel cell electric vehicles in India. In Towards Hydrogen Infrastructure (pp. 379-400). Elsevier. DOI: https://doi.org/10.1016/B978-0-323-95553-9.00005-4

Stępień, Z. (2021). A comprehensive overview of hydrogen-fueled internal combustion engines: Achievements and future challenges. *Energies*, *14*(20), 6504. DOI: https://doi.org/10.3390/en14206504

Wouters, M., Anderson, J. C., & Wynstra, F. (2005). The adoption of total cost of ownership for sourcing decisions—a structural equations analysis. *Accounting, organizations and society*, *30*(2), 167-191. https://doi.org/10.1016/j.aos.2004.03.002

Wouters, M., & Morales, S. (2014). The contemporary art of cost management methods during product development. In *Advances in Management Accounting* (pp. 259-346). Emerald Group Publishing Limited. DOI: https://doi.org/10.1108/S1474-787120140000024008

Zengin, Y., & Ada, E. (2010). Cost management through product design: target costing approach. *International Journal of production research*, *48*(19), 5593-5611. DOI: https://doi.org/10.1080/00207540903130876