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Are We Missing the Bus? A Case Study on Flexibility Options for Charging Infrastructure at the Amsterdam Central Station

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Abstract: Is it possible for flexible applications of infrastructure to help cope with the demand for space? In this paper we tried to answer how different forms of flexibility can impact the societal costs of infrastructure development on passenger transport hubs. For this explorative research option, the value is used to determine these impacts. It is applied to charging infrastructure for electric buses at the Amsterdam Central Station. It shows the challenge in setting up a collective approach towards attaining the optimal societal impact, due to limited knowledge on the potential of flexibility, the complexity in setting up a win-win for each stakeholder based on their different interests and the lacking ownership of the overall collective impact that can be made. The remaining question is, will there be a way out?

Keywords: flexibility; forms of flexibility; option value; passenger transport hubs

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Citation: Pennings, R.; Wiegmans, B.; Spit, T. Are We Missing the Bus? A Case Study on Flexibility Options for Charging Infrastructure at the Amsterdam Central Station. *Infrastructures* **2023**, *8*, 47. https://doi.org/10.3390/infrastructures8030047

Academic Editor: Isam Shahrour

Received: 26 January 2023
Revised: 27 February 2023
Accepted: 27 February 2023
Published: 7 March 2023

1. Introduction

The pressure on passenger transport infrastructure is rising due to growing urban populations and growing demand for urban transport [1]. At the same time, the transitioning of the mobility system towards zero-emission mobility [2] leads to an integration of the electricity and transport sector [3]. This adds to the growing demand for charging infrastructure and requires an urgent understanding of how urban areas can cope with these transitions in changing environments. By investigating different options for the applicability of infrastructure for both current and future use, a trade-off between current need and flexibility for the future can be found. This requires an understanding of the role flexibility can play in making effective use of existing and new infrastructure.

A potential application is new infrastructure for mobility in the energy transition. For the Netherlands, the energy transition brings an increase in demand for electricity [4], which leads to rising demand for grid infrastructure [5]. Due to limited available grid capacity, a grid connection with the security of electricity supply is no longer guaranteed [6]. At the same time, the increased application of battery electric zero-emission buses for public transport [7,8] leads to growing demand for charging infrastructure [9], which requires significant grid connections and is mostly located on mobility hubs [10]. Therefore, this explorative paper focuses on the bus charging infrastructure at the Amsterdam Central Station Area (ACSA). This area is chosen due to its growing electricity demand for mobility purposes and easy access to stakeholders for research purposes. At the same time, the growing electricity demand and realisation of charging infrastructure on bus platforms applies to many hubs, and therefore the findings from this paper can offer insights for other locations. Since flexibility can help make today's investments more adaptable for changing demands, it thereby can potentially lower future costs. This emphasizes the importance of understanding and acting on the flexible capacity of infrastructure design and use in environments with forced preconditions.

Where demand for space is high and fixity of transport infrastructure exists [11], the pressure on available space increases, as is the case for urban transport hubs [12]. Furthermore, a lack of sufficient resources today leads to increased overall costs for municipalities over time [13]. This, combined with the likely remaining type of land-use once set [14] and the slow pace of the reworking of infrastructure compared to other changes in the metropolitan area [15], indicate that short-term solutions for high pressure areas can lead to long-term consequences. With the growing complexity of the municipal organization and the number of stakeholders involved [16], decision making proves challenging in governance. Furthermore, the uncertainty of future transport infrastructure needs [17] leads to the risks in the future usability of infrastructure. To reduce risks of spending scarce private and public resources on infrastructure solutions that are not efficient or interoperable [18], a full understanding of the system at play is needed. With limited available resources, this highlights the dilemma of decision making, both for the short- and long-term planning of infrastructure on hubs. It emphasizes the importance of setting up a governance approach that can deal with this uncertainty.

A potential way to limit the consequences of uncertainty in decision making is by applying flexibility in the system. Flexibility is defined by 'the ability to be easily modified' [19], which means infrastructure can be adjusted with relative ease to cope with new demands. Flexibility exists in many different forms, such as with physical infrastructure, management or stakeholders. Since flexibility might reduce costs of future developments [20], this can also be attributed to limiting the consequences of uncertainty in decision making; it is seen as crucial under uncertainty for policy design [21]. Together with the potential of linking futures with policy making to choose preferred courses of action [22], this shows the importance of getting a better understanding of the potential of flexibility and the forms of flexibility.

The question is how can the potential of flexibility be identified? Option value offers an opportunity to do so [20,23], since the potential of different options is made explicit and can be applied in the trade-offs in decision making. This enriches governance theory as a methodological approach since it can help indicate possible development trajectories and can be a valuable addition in Cost Benefit Analysis [23]. This underlines the importance to integrate the flexibility of infrastructure with an option value to help decision making.

The goal of this explorative research is to develop a qualitative understanding of the governance and impact of the options for flexibility on passenger transport hubs. This is integrated into the following research question: How can flexibility for infrastructure on passenger transport hubs impact the societal costs for all stakeholders by using option value? In this research, an option value is applied in a qualitative and not quantitative study, which shows the innovative aspect of the application of an option value. This empirical research develops a framework of the concept of flexibility and the potential approach to incorporation of the option value into infrastructure development. It indicates the promising future focus areas for the application of a flexible option value in infrastructure design.

2. Forms of Flexibility and the Application of Option Value

This literature review focuses on flexibility in relation to governance of infrastructure. The approach is based on the different elements of governance. Its definition in transportation, based on Rodrigue, is that 'governance concerns the ownership and management of assets and resources to fulfil goals such as profit or welfare through the exercise of authority and institutional resources. It concerns the public as well as the private sectors but tends to apply differently depending on if public or private interests are at stake. In both cases, a significant concern is performance, which is how effectively available assets are used' [24]. The definition indicates that *governance* is related to the *management (and ownership)* [element] by *stakeholders* (public/private parties who own and/or use the physical infrastructure (assets)) [element] and the *physical infrastructure* [element]. Based on the usage of the physical infrastructure, the *goal(s) of the infrastructure* [element]—which can be profit, welfare or both—can be met. The impact of time on the usage of the physical

infrastructure is in the changing goals over time. This logic is used to structure the findings, as is visualised in Figure 1. The different building blocks are each further discussed below and followed by a review of the option value literature and its applicability for flexibility in infrastructure.

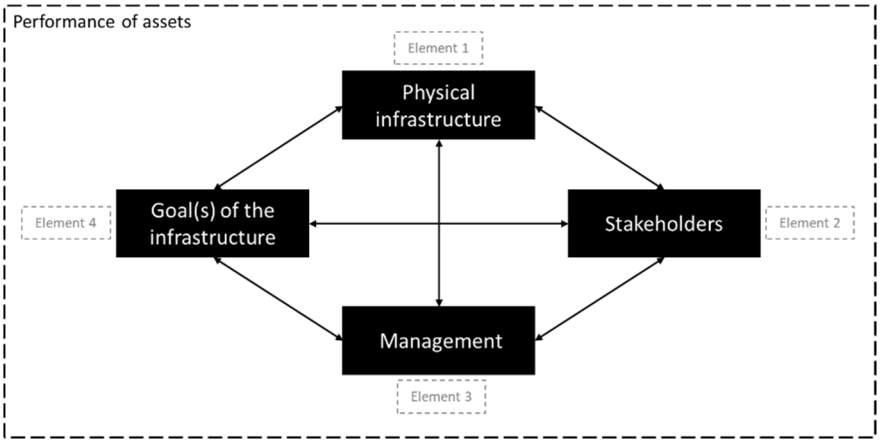

Figure 1. The relation between the goal(s) of infrastructure, physical infrastructure, stakeholders and management.

2.1. Element 1: Physical Infrastructure

Physical infrastructure is developed for a certain use. Depending on the demand, this use can be adjusted. As introduced by Roggema, several physical possibilities for flexible adjustments in physical space exist, such as creating multiple layers for urban activities, easing the way objects are constructed or re-using abandoned spaces) to deal with sudden, surprising and unprecedented impacts. This allows infrastructure to reconfigure itself [25]. This flexibility of the design of physical infrastructure is essential to have options to deal with future uncertainties [26]. This underlines that physical flexibility is open to multiple interpretations and applications and indicates the flexibility of physical infrastructure as a form of flexibility (element 1).

2.2. Element 2: Stakeholder Involvement

Collaboration between stakeholders is necessary to provide the variety of benefits that parties individually cannot achieve [27]. This requires shared aims to achieve a sustainable collaboration [28], clear division of responsibilities [29] and a win-win for the involved private and public parties (including fair risk sharing and a minimum profit for private parties) [27]. Since different stakeholders have a range of different preconceptions that help each stakeholder to make their own decisions based on their perception of the situation and the future [26,30,31], this shows a potential gap between stakeholder's own aims and the needed shared aims in collaboration. This emphasizes the challenge in finding common aims between stakeholders and shows variety in the potential added value by involving different stakeholders in a collaboration. It requires an overview of the added value per stakeholder to determine which stakeholders to best involve in the development and operation of infrastructure. This indicates the flexibility in which stakeholders can be involved as a form of flexibility (element 2).

2.3. Element 3: Management Approach

In the literature, there is much available on approaches to management in the governance of public infrastructure [32–35], showing different possible setups for management of collaborations. These setups have different challenges, such as the sharing of risks [27,36], fragmentation of ownership [37], different strategic focus between public and private parties [30], balancing between project-based goal orientation and higher-level processes [31], different levels of government that come together [38] and setting up shared goals [39]. De-

pending on the situation, the way management is set up can limit these challenges. For the initiation of this collaboration, public stakeholders can have a more entrepreneurial role in creating clarity for other stakeholders [38], they can be seen as having more influence than private parties in collaboration [40] and they have the necessary political leadership [41]. This indicates the potential role for a public stakeholder as an initiator. For smoothening the initiation and collaboration, a possible role exists for boundary spanners [42,43]. The role of initiator depends on the scope of the goals and the local context. Given the development of uncertainties and risks for stakeholders [44] and different needs per phase [40], the dynamics of the collaboration and the network of stakeholders can change over time. This shows that the management approach needs to address several challenges and can change over time, depending on the goal(s) of the collaboration. Since flexibility within the decision-making process can have a positive impact on improving the performance of infrastructure [45], it can add value to infrastructure management. Overall, the possible approaches towards management and which party initiates collaboration show flexibility in management approach as a form of flexibility (element 3).

2.4. Element 4: Goal(s) of Infrastructure over Time

Challenges for infrastructure include the changing of its goals and thereby its use over time. Since flexibility in time and use contributes to the efficiency of interchanges [46], it shows to be an important element in infrastructure development on passenger transportation hubs. Flexibility and agility are needed over time due to rapid changes in demand, service conditions and environmental conditions [47]. An adaptive approach has potential towards disruptive developments based on new arising insights over time and is useful in dealing with uncertainties [48] and delays between the time of decision making from the start of an infrastructure project to its completion [49]. This is relevant when stakeholder interests change over time. Furthermore, current models such as Life Cycle Analysis do not fully include the aspect of changeability over time to deal with unforeseen future developments efficiently [50], which highlights the relevance of the flexibility to make changes over time based on new developments. It indicates flexibility of goals over time as a form of flexibility (element 4).

2.5. To Conclude: Four Forms of Flexibility Are Identified

Next to flexibility in the physical infrastructure, three other forms of flexibility have been identified: flexibility in which stakeholders are involved, flexibility in management approach and flexibility of goals over time. These are further explained in Table 1 and the corresponding indicators are given in Table 2.

Table 1. Description of the different forms of flexibility.

Form of Flexibility	Description
Flexibility of physical infrastructure [25,26]	This indicates the level in which physical infrastructure can be adjusted to new needs. It means that during the design phase additional requirements (in e.g., function, space and design) are met to make future adjustments easier.
	Example: To what extent can charging infrastructure for simultaneous charging of 5 electric buses be extended to 10 busses. Does this require a similar project to build the physical infrastructure (charging poles, cables and technical systems) again or are there options with the existing infrastructure to limit these costs.
Flexibility in stakeholder involvement [26,28,37]	This indicates the manoeuvring space available for including or excluding certain stakeholders and their scopes in the development and operation of physical infrastructure.

Table 1. *Cont.*

Form of Flexibility	Description
	Example: Charging infrastructure is developed by a combination of parties. If a new party wants to join the usage of this infrastructure (e.g., for charging a third-party bus or truck), will this be made possible by the current parties or not?
Flexibility in management approach [27,29,30]	Flexibility in management approach indicates the way the collaboration in infrastructure use between stakeholders is organised. The level of flexibility in this collaboration leaves room for changes over time.
	Example: A management approach can be where one party is owner and responsible for the infrastructure and other parties pay for usage. To what level is this approach flexible for changes in demand for this infrastructure?
Flexibility of goal(s) over time [46–50]	This indicates the level of flexibility in change in the goal(s) for the infrastructure over time and to what extent it is capable to deal with these new goals.
	Example: Next to charging busses, the infrastructure can be used to charge other vehicles as well. To what extent are parties willing and capable to let this change happen?

Table 2. Indicators for the forms of flexibility. The measurement of the indicators is conducted via interviews.

Indicators for the Forms of Flexibility:
• The level of willingness of a stakeholder to invest in this form of flexibility. • The expected level of impact (factor) this kind of flexibility can have versus its costs. • The level of willingness from involved stakeholders to allow stakeholders to join or stop involvement. • The (consideration of) application of flexibility elements in the setup of the collaboration. • The preferred type of setup for stakeholders and management. • The perceived change in goals over time

2.6. Option Value Helps Indicate Where Flexibility Can Add Value

Option value is described 'as the valuation of choice options as a backup for other options or for future use' [23]. It can be used to value the forms of flexibility, since it compares different options of flexibility to a do-nothing situation. Given the difficulty in attaining sufficient confidence in developments over time and subsequent valuation [51], the option value offers a way to see the potential of in investment in different development paths and compare its costs and benefits to other investments [49]. The option value shows potential to valuate flexibility by making the potential of the forms of flexibility explicit and achieve insight on which option(s) of the forms of flexibility can achieve most benefit.

2.7. A Framework for Flexibility

The framework in Figure 2 gives an overview of how different forms of flexibility lead to options, and how these options lead to eventual decision making on the best fitting options to reach the set societal goal based on the available resources. Money is used as the dependent variable in the framework, since physical infrastructure investments, resource application and time can be valued in money.

2.8. Methodology

The qualitative application of option value on flexibility means that for each form of flexibility different options exist. To get an understanding of how flexibility options can

impact the societal costs in passenger transport infrastructure, it is important to build an understanding of how stakeholders see the expected added value of (i) each of the different forms of flexibility on societal costs and (ii) options per form of flexibility on societal costs. To understand how the lessons from the literature and this framework work in real-life, the theory will be put into practice in the ACSA case.

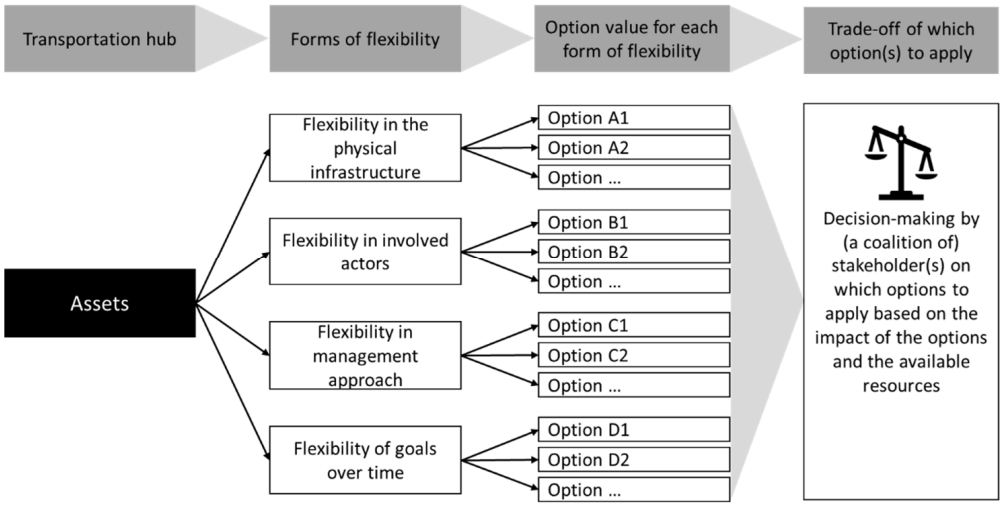

Figure 2. The framework of the application of options theory on forms of flexibility.

3. The Study Object: Amsterdam Central Station Area

The scope of the ACSA case focuses on the relation between infrastructure (electricity) and planning (transport), given the societal urgency of this matter. The geographical scope is chosen since it has recently seen the development of charging infrastructure for buses [10]. It consists of one major station structure combined with transport infrastructure as indicated in Figure 3. The spatial focus is on the physical area of the bus platform, which is needed for the different transport providers which use charging infrastructure or might use it in the future. It includes the platforms and supporting electricity infrastructure for the charging of buses (from grid connection to the platform). This includes the use and availability of physical space and infrastructure. Tram, metro, train and ferry infrastructure are outside the direct scope due to limited current shared infrastructure applications.

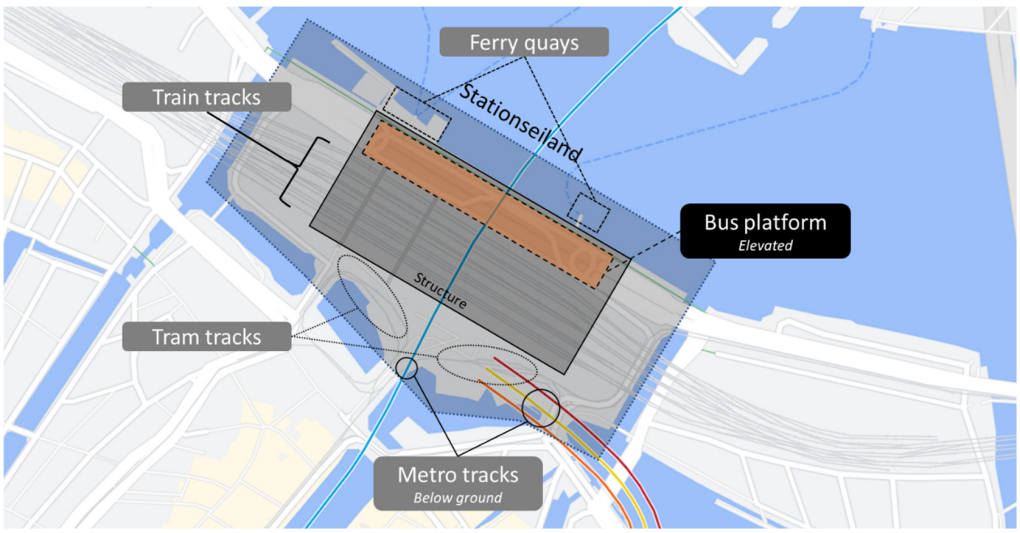

Figure 3. The physical transport infrastructure at Amsterdam Central Station. The train, tram and metro tracks and the ferry are outside of scope.

Next to the spatial focus, the management of the different elements of hubs and their cooperation is included. Different organizations are responsible for part of the functioning of the hub, including the municipality, public transport providers, transport authority and the distribution system operator (DSO). For the ACSA case, the responsibilities of the stakeholders are given in Table 3.

Table 3. The responsibilities of the stakeholders in the ACSA case.

Actor	Responsibilities
Municipality of Amsterdam	The municipality is responsible for public space in and around the central station. This includes roads, cycling paths, walkways, parking, the Michiel de Ruyter tunnel (running underneath the Central Station) and has its own hub strategy towards the development of (shared) transport in and around the city. Different departments of the municipality have different responsibilities. Relevant departments are Verkeer en Openbare Ruimte, Ruimte en Duurzaamheid, Grond en Ontwikkeling and Deelnemingen. The municipality has—as a public party—a broad societal perspective. The municipality is a shareholder in the GVB (transport provider), Vervoerregio Amsterdam (transport authority) and Liander (DSO) [52].
Transport authority	The transport authority (Vervoerregio Amsterdam) is a public collaboration of 14 municipalities. It is responsible for the concessions of the public transport in Amsterdam. Part of the concession requirements are zero emission transport, which requires charging infrastructure in strategic locations and subsequently leads to demand on the grid. The Vervoerregio supports sharing of charging infrastructure between different users [53].
Transport providers	Different transport providers use Amsterdam Central Station, and the electrification of these transport modes impacts the requirements on the grid. This includes: • GVB has the concession (metro, tram, bus and ferry) for the Amsterdam area and is the main user of the bus platform at the ACSA area. GVB is a private (GVB Exploitatie BV) party which is owned by the municipality of Amsterdam and the Vervoerregio Amsterdam. Apart from the transport concession, GVB Infra BV also has the concession for the management and maintenance of the rail infrastructure [54]. • Connexxion and EBS are transport providers from bordering concessions (bus) to Amsterdam. Several bus lines have the possibility to use Amsterdam CS. This can—with further electrification of the bus fleet—also develop the need to charge buses at Amsterdam Central Station. Both parties are private companies.
DSO	Liander, the DSO for ACSA, is responsible for providing the physical infrastructure to provide the required electricity cables to a user [55]. This covers a public interest.

The stakeholders and their respective responsibilities divide the ownership of the placement and use of the charging infrastructure, which requires collaboration. The stakeholders for the scope of the research and the ownership are shown in Figure 4.

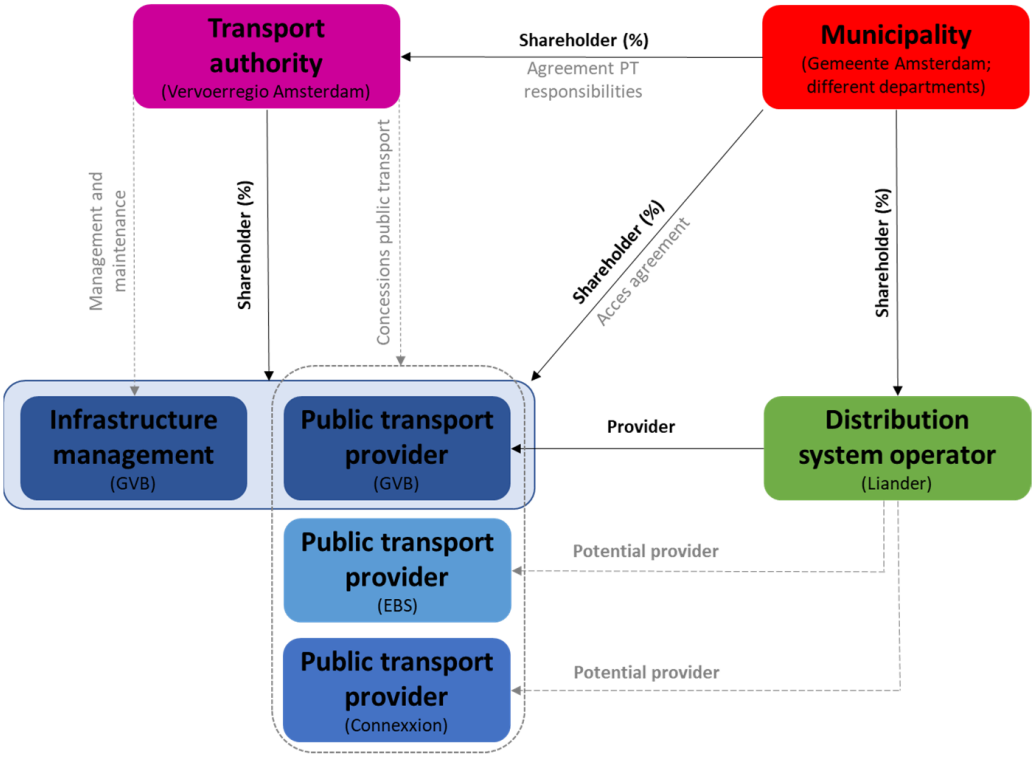

Figure 4. The ownership relations between the different involved stakeholders at ACSA [52–54].

The focus of the research is on the governance of this charging infrastructure for buses since it combines the important interfaces for the infrastructure development of the area. The timeline is set from current to future developments for the period until 2040 since it incorporates multiple concession periods for public transport.

Forms of Flexibility in Relation to the Stakeholders at ACSA

For each stakeholder in the ACSA case, each form of flexibility has a specific meaning. Table 4 gives an indication of this meaning per form of flexibility per stakeholder. This list is—due to limited space—not exhaustive.

Table 4. The meaning of the forms of flexibility in relation to each stakeholder.

	Flexibility of Physical Infrastructure	**Flexibility in Stakeholder Involvement**	**Flexibility in Management Approach**	**Flexibility of Goal(s) over Time**
Municipality of Amsterdam (public)	Relevant to the amount of space needed for extensions in relation to other developments	Relevant for the number of stakeholders using infrastructure and the overall amount of needed space	Relevant for the scope of the infrastructure use and operational responsibilities	Relevant to adaptive use of the space and infrastructure over time
Transport authority (public)	Relevant for lowering overall (societal) costs for new concessions	Relevant for lowering overall (societal) costs for the current and new concessions	Relevant for the scope of the in-frastructure use	Relevant for lower (societal) costs through multi-use over time

Table 4. *Cont.*

	Flexibility of Physical Infrastructure	**Flexibility in Stakeholder Involvement**	**Flexibility in Management Approach**	**Flexibility of Goal(s) over Time**
Transport providers (private)	Relevant for lowering costs by sharing infrastructure or grid connections	Whether or not other parties can use their infrastructure or they can use other party's infrastructure	Relevant for the usage agreements and private versus shared flexibility of the system	Relevant for lower costs through multi-use over time
DSO (public)	Relevant to the overall impact of demand on the grid	Relevant to the overall impact on the grid	Relevant to the overall impact on the grid	Relevant to the overall impact on the grid and demand for new grid connections

4. The Case Study for Charging Infrastructure at Amsterdam Central Station Area

4.1. Data Collection for the Case

By investigating forms of flexibility and option value for charging infrastructure at ACSA, the potential impact of flexibility is explored. An analysis scheme with corresponding questions based on the literature review is set up to understand how forms of flexibility and option value can impact the societal costs of infrastructure. The case study is based on interviews with the stakeholders. Interviewees were selected based on the relevance of their role and experience with the case, having sufficient representation and views from each stakeholder and by asking each interviewee who they thought were the relevant persons to interview. A total of 13 people (see overview of interviewees in Table 5) were interviewed during the period April–June 2022 with at least two interviewees per stakeholder type. The interviews consisted of an explanation of the case study, the involved stakeholders, the definition of societal costs and the introduction of the forms of flexibility. For each interview a report was made, checked by and agreed upon by the interviewee. All stakeholders were asked to answer the questions from their single stakeholder's perspective. The results of these interviews were analysed and these results are presented below.

Table 5. The overview of interviewees.

Organization	**Roles of Interviewees:**
Municipality	• Strategist, • Energy Consultant, • Project manager zero-emission bus • Strategic advisor program touring car
Transport Authority	• Senior policy advisor zero-emission • Program manager for clean and sustainable
Transport Providers	• Program manager zero-emission bus (GVB) • Project lead charging infrastructure ACSA (GVB) • Energy & Environment manager (GVB) • Senior project manager zero-emission (Connexxion) • Manager (EBS)
DSO	• Relation Manager (ACSA) • Consultant energy storage and systems)

4.2. The Main Results of the Interviews

In the part below, the results of the main findings are indicated per topic:

- The perception of flexibility is mainly focused on physical infrastructure and time, while added value is seen for all four forms of flexibility. The interviews indicated that—when asked without any prior knowledge on the forms of flexibility—all interviewees mentioned both the flexibility of physical infrastructure and flexibility of goals over time. Flexibility in management approach was mentioned in less than half of the interviews and flexibility in stakeholder involvement was mentioned in two interviews. These results indicate a strong perception towards the flexibility of physical infrastructure and goals over time. When asked how one perceives the weight of contribution to societal impact, with each form of flexibility compared to other forms (interviewees had 100 points to divide over the four types of flexibility), the results are far more balanced, with flexibility of physical infrastructure, flexibility of goals over time and flexibility in stakeholder involvement getting a similar number of points. Flexibility in management approach followed shortly behind. This shows that when forms of flexibility are not known for all stakeholders, this leaves a bias in decision making towards the known forms of flexibility.
- A collaboration with clear ownership, roles and responsibilities is key for successful management. Regarding the logical setup for the management to cope with flexibility, most stakeholders do recognize the need for a collaboration of stakeholders with one directing party. As directing party of this collaboration, most parties see the municipality as a logical choice due to its societal perspective. In cases with limited stakeholders (>three), the main user (transport provider) is mentioned as a logical directing party.
- Fragmented ownership and interests call for an initiator for collaboration. An initiator brings different parties together with the responsibility of achieving mandate for collaboration towards optimal collective societal costs for all stakeholders. When asked about the most logical initiator for the forms of flexibility, the answers of the different stakeholders vary over the municipality, transport authority and transport provider. As indicated in the interviews, this is due to the scope of the infrastructure use and whether this is a proactive approach (based on policy) or reactive (based on an arising need). If addressed from a societal perspective, the municipality is seen as a logical initiator, followed by the transport authority (with a societal focus mostly on mobility). If the focus is more on the operational side and needed efficiency (as set in the goals and scope of this stakeholder), the transport provider is seen as the logical choice. Furthermore, it can be influenced by the local context, such as land ownership, and by which party is the main financer. As indicated by an interviewee of the municipality: "Since each party is aimed at their own assignment and efficiency, the (in)direct owner of the location is in a logical position to take charge". The results indicate a variety in perspectives on the most logical party to take the initiative.

The findings of lesser importance include:

- Interviewees in general expect added value by applying form(s) of flexibility. The expected added value for each form of flexibility is seen as positive by all interviewees. This means that the return on the investment is seen as higher than the initial investment. Interviewees tend to see more added value in the flexibility of physical infrastructure and flexibility of goals over time than for stakeholder involvement and management approach. Examples by interviewees for flexibility applications include the sharing of bus charging infrastructure between public transport providers, touring car operators or logistic parties and the use of the grid connection for charging infrastructure on other nearby locations for taxis or ferries. As indicated by three interviewees, the potential synergy between the application of more forms of flexibility is expected to lead to a combined higher added value than for each form of

flexibility separately. For example, the physical infrastructure and time can influence the possibilities of management and stakeholders.

- The municipality expects higher added value than private stakeholders. It is remarkable that the perception of interviewees from the municipality (public party) on the added value of flexibility is significantly higher than how transport providers (private parties) perceive its added value. The interviewees from the municipality stressed the positive effect on the broad societal impact, as said by one interviewee: "The societal impact applies for the location as well as for other locations for investments that do not have to be made". Other stakeholders focused more on the importance of flexibility for their business case. As said by a transport provider: "It introduces extra risks for the organization, and thereby the business case".
- Most stakeholders are willing to invest in flexibility if it has a high probability of success. On the question whether their organization is willing to invest in the different forms of flexibility, all interviewees (based on where they could answer that question. Answer was either 'yes' or 'not applicable') from the municipality, transport authority and the DSO answered positive. Answers from the transport providers were mixed (yes/no) as these interviewees indicated the limited scope of private companies compared to public parties and the potential risks of flexibility as main reasons. In situations where this risk is mitigated, they show willingness to invest.
- Stakeholders are open to share infrastructure if its benefits outweigh its costs and risks. The willingness to share infrastructure is in general positively perceived by the interviewees. On the public side this is mostly due to the societal benefits and on the private side lower costs are indicated as the main motivation. Constraints are that this should not interfere with the operations of the (primary) user(s) and it requires a trade-off of limiting one's own stakeholder-specific flexibility versus gaining collective flexibility. In general, the thought is that starting and stopping in the cooperation should be without significant negative consequences for other parties. As said by an interviewee of the transport authority: "As long as it does not hinder the primary user". The interviews show that both public and private parties anticipate potential added value in sharing infrastructure.
- Flexibility of goals over time has potential due to growing technological possibilities. The aspect of flexibility of goals over time is perceived by the interviewees in both the short (over the day to over a few months) and long term (over a period of years). For the short term, in general the need for flexibility grows due to the urgence in the challenges with the energy network. This shows in ACSA in the high number of simultaneous electrification projects for mobility, which lead to pressure on the available capacity of the DSO and municipality. For the long term, the development of technology and changing requirements for infrastructure and space has potential for infrastructure to be used in different ways and to bring further future benefits. In general, the perception of the interviewees of flexibility of goals over time can offer potential for adaptive approaches.

4.3. Discussion of the Results

As seen in the interviews, the perception of flexibility is mainly focused on physical infrastructure and time, while added value is seen for all four forms of flexibility. This implies a bias in decision making towards the known forms of flexibility. Since flexibility is a broad topic with many different perceptions of its forms [20], this means that decision making without a full understanding of the forms of flexibility can lead to suboptimal choices being made. It shows the importance of decision makers having significant upfront understanding of how flexibility can be applied and impact projects. Furthermore, interviewees in general expect added value by applying form(s) of flexibility. The findings regarding the potential added value are in line with the expected positive added value of flexibility [20]. Although the empirical evidence for this case and the literature indicates the potential for positive added value, it is not to be expected for all stakeholders to perceive

positive added value in all cases. Overall, this shows that flexibility has the potential to add value. It is of interest that the municipality expects higher added value than private stakeholders. These different perceptions of added value between stakeholders is similar to the existing literature on goals in collaboration [30,31]). It is to be expected that, given the broader societal scope of public parties, that their expected added value is higher. This indicates the importance of building knowledge on how different stakeholders perceive added value of flexibility, to understand which combinations of stakeholders and forms of flexibility can lead to the highest potential added value. A further point of interest is that, when a combination of options for flexibility is made, whose responsibility it is to take further action in achieving this and unlock the potential benefits?

The need for a collaboration with clear ownership, roles and responsibilities for the successful management of collaboration in regard to flexibility—as seen in the interview results—is in line with the literature [27,29,36–38]. Since collaboration for the setup of a collaboration requires clear agreement on ownership, roles and responsibilities, these elements need to be addressed. Although a clear insight on ownership, roles and responsibilities is given for the collaboration, this collaboration does not develop by itself. Therefore, the question is why this collaboration is not initiated in the case and in general. This fragmented ownership and interests call for an initiator for collaboration. The literature indicates that public stakeholders (such as the municipality and the transport authority) have more influence than private parties (transport provider) in collaborations [40], which put the public stakeholder in the initiator position. As indicated by Priemus, public stakeholders can have a more entrepreneurial role in creating clarity for other stakeholders [38]. This is strengthened with the necessity of political leadership in the development of sustainable transformations [41], and that strong experience with an area and sector(s) is of strong added value for initiating parties [42], as is the case for public stakeholders. Based on both the literature and the interviews, this shows mainly that based on the way the scope is set (number of stakeholders involved), the most logical initiator can be found with private parties (approx. $<$ three stakeholders) or public parties (approx. $\geq$ three stakeholders). The case study and literature show that for the ACSA case, the municipality is in a logical position to be the initiator, given their broad societal scope and their (in)direct influence (through ownership) on all main public stakeholders involved as well as GVB. One important note is that different departments within a stakeholder can have different internal interests, which require trade-offs. For the municipality, this can be for example different interests between Deelnemingen and Verkeer & Openbare Ruimte. These different perspectives per stakeholder indicate the importance of finding a common approach from stakeholders internally as well.

The interviews show that most stakeholders are willing to invest in flexibility if it has a high probability of success. This is in line with Klijn and Teisman's findings on the limited risk in collaboration of private stakeholders [30]. It indicates that stakeholders are willing to invest in flexibility under certain conditions. Currently, the Amsterdam bus concession has very limited incentives for the transport provider to further apply flexibility, which limits the transport provider's focus on investment opportunities in this area. Furthermore, stakeholders are open to share infrastructure if its benefits outweigh its costs and risks. The literature on stakeholder benefits from collaboration indicates the importance of creating a win-win so that each party benefits from the added value as created by the collaboration [27]. This requires specific attention for a fair division of the benefits, costs and risks. For the case, this does answer the question of how these costs, risks and benefits—which can be both financial and societal—are divided across the stakeholders. This leads to the question of if a (combination of) stakeholder(s) can initiate and develop these conditions. It is recommended that further investigation is conducted on the topic of the distribution method for benefits, costs and risks. This requires attention for each stakeholder's interests and the division of this added value of a collective approach versus the sum of the societal costs for individual approaches.

For flexibility of goals over time, growing technological possibilities indicate potential, such as that described by Walker and Marchau [48]. It does show that the adaptive potential over time needs to be unlocked. However, an approach to do this is currently not in place for the ACSA case. By actively securing this approach in the management of these assets, this can help to prepare stakeholders to apply the infrastructure for future arising needs. At the same time, it does require a balance with keeping clear goals for the development and flexibility for further usage. This requires the development of a management system between stakeholders which has potential adjustments based on—currently known and unknown—future needs in scope.

4.4. Reflection on the Case and Its Added Value

Limited flexibility and option value for flexibility has been applied in the case of charging infrastructure for electric buses at ACSA. The consensus of the interviewees was that from a societal point of view, chances have been missed in adding value through applying flexibility options. Interviewees indicated that this was due to (1) limitation in the scope for their projects, (2) different scopes per stakeholder, (3) limited available time for the preparation and realisation of these projects, (4) a lack of collective push on a collective agreement and mandate, and (5) taking up certain roles is not allowed by regulations in the case of the DSO. It is understood by the interviewees why this happened, but still considered as a loss for the potential societal value that could have been added. Overall, this shows a fragmented way of working, which misses an overarching direction since there is no clear problem owner. To increase the potential of flexibility in future projects, this case did show the importance of setting up a proactive collaboration and grant the mandate to an initiator and director to—from the perspective of a societal optimum—steer for the best fitting solutions.

The case gives a real-life picture of the potential of flexibility. It showed the importance of starting early with the initiation for the application of flexible infrastructure to align interests, scopes and develop a collaboration. However, the project in the case has been finished and indicates a suboptimal application of flexibility. The interviewees showed in general that an explicit approach towards flexibility would have given them a better understanding and way of working to apply flexibility, which would have potentially increased the application of flexibility in the project. This shows the importance of investigating flexibility options right at the start of project initiation in complex multi-stakeholder environments such as transport hubs. This goes both for the ACSA case as for other transport hubs. In other words: if one does not see it and it's not pointed out, they perceive it as not being there.

5. Conclusions

The main question to be answered is: How can flexibility for infrastructure on passenger transport hubs impact the societal costs for all stakeholders by using option value? The answer is that the identified forms of flexibility—flexibility of physical infrastructure, stakeholder involvement, management approach and goal(s) over time—can impact the societal costs by giving decision makers an overall overview of which options of flexibility for their infrastructure application are available and which impact they can have. This gives decision makers the opportunity to make an overall trade-off of (a combination of) the best fitting option(s) based on available resources. Regarding the challenge in initiating this approach towards attaining this optimal societal impact, the question of whether there will be a way out can be answered positively for ACSA: four areas of attention for further research and/or application are found in the development of this paper which will offer this way out.

1. Address the lack of knowledge on the potential of the 2 additional forms of flexibility. The perception of stakeholders on flexibility is mainly focused on physical infrastructure and time, while all stakeholders see added value for all these two as well as the other two forms of flexibility (stakeholder involvement and management approach),

since all can contribute to lowering costs, lowering pressure on stakeholder capacity and quicker realisation times of projects. This is in line with Pennings et. al. [20] since it emphasizes that the lack of understanding of the potential of all forms of flexibility leads to lost potential in added societal value. It highlights the importance of sufficient initial knowledge on the potential of flexibility in infrastructure project development.

2. Secure the overall benefit per stakeholder in the collaboration. The case shows that stakeholders are willing to invest and are open to share infrastructure if the benefits outweigh the costs and risks. For achieving a collective approach based on societal costs, this requires the collaboration to lead to an overall win-win, which is in line with the existing literature [27]. From the perspective of the framework, all four forms of flexibility have the potential to give a positive added value such as lowering (societal) costs in design and realisation, although the perceived added value per form of flexibility for each stakeholder differs due to each stakeholders' own interests. This introduces a complicated puzzle and trade-off for decision-makers and indicates the importance of developing a method to make this collaboration work beneficial for each stakeholder.
3. Find an overarching problem owner. Fragmented problem ownership leads to the lack of an initiator to start the collaboration. Without this, every stakeholder solves their challenges individually, leading overall to higher costs and more required capacity. Although the literature puts the overarching problem ownership in the direction of public stakeholders [40], the basis for this is in the political leadership and not the overarching overview of the societal impact of the system at play. This shows a gap in the literature on the question of who should take responsibility for achieving collective societal benefit. This missing problem ownership causes a stalemate: to let flexibility options help optimise the impact on collective societal costs, one clear problem owner is needed with the responsibility of initiating the application of flexibility options. This case shows that due to the municipality having a higher perception of added value due to the range of both societal and financial benefits, it is the likely stakeholder that takes the lead as the overarching problem owner.
4. Introduce an overarching level of organizing ability. Since each stakeholder is set with its own 'classic' scope, goals and responsibilities, these stakeholders lack the mandate to address the collective societal impact. The overarching problem owner can help initiate the collaboration. With the integration of different sectors, which in the past had limited interfaces, and the addition of flexibility, this collaboration requires a scope encompassing this perspective. By setting an overarching scope within this collaboration, which includes both the societal and the stakeholder-specific perspectives, stakeholders can work together towards achieving optimal societal impact within this perspective. The key in arranging this lies in introducing the organizing ability to bring these stakeholders together and to have the collective mandate to facilitate and direct this process. This organizing ability needs a mandate from the stakeholders to achieve this societal optimum collaboration focused on the scoping of this perspective. It does require an up-front financial, capacity and time investment since it requires a more extensive initiation phase to identify the best-fitting flexibility options, but can bring benefits in the following project phases, such as less total required infrastructure and lower operational expenses.

As we can see, for Amsterdam there is a way out. The question now is whether this is also the case for other hubs? Since the challenges facing ACSA—such as growing electricity demand and limited available space—are similar to other hubs, the insights of this paper can help indicate the potential of forms of flexibility for other hub locations. The issue – with no stakeholder being responsible overall for the total of the scope of the collective societal costs – is applicable to more types of infrastructure. It is recommended to further address the issue of the ownership of these types of infrastructure and then further fill the role, responsibilities and way of working for the initiator, director and collaboration. This is cause for further research. At the same time, further research on

different cases is recommended to broaden the understanding of the potential impact of each form of flexibility.

To conclude, the overarching connection between infrastructure and forms of flexibility, as shown in this paper, is not covered by the sum of the single pieces of the used existing literature. Ironically, it indicates fragmentation in the existing body of literature towards flexibility. It shows the limited existing knowledge on both flexibility for passenger transport hubs and in creating additional organizational ability in the development of flexibility in infrastructure development and use. This paper makes clear that the way we have been organising our (transport and energy) infrastructure does not fit our current and future needs, and we will do ourselves short if we keep organizing it in this classic way. Therefore, the organizing ability for flexibility is a promising focus area to start making better use of our infrastructure.

Author Contributions: Conceptualization, R.P., B.W. and T.S.; methodology, R.P., B.W. and T.S.; interviews, R.P.; writing—original draft preparation, R.P., B.W. and T.S.; writing—review and editing, R.P., B.W. and T.S.; visualization, R.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data sharing not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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