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From Supply Chain Stakeholder to Service Customer: An Engineering Framework for Vehicle-Based Services

C. Pizzinini ✉, J. Bercher and M. Lienkamp
Chair of Automotive Technology, Technical University of Munich, Germany
✉ clemens.pizzinini@tum.de

Abstract
Geographic distance between supply and demand reduces spatial accessibility. Vehicles have been contributing to improved spatial accessibility by offering transport services for people and goods. From traditional trucks to mobile health clinics, vehicles can offer a wide range of functionalities on wheels. To develop context-specific vehicles-based services, we propose a novel engineering framework based on a supply chain perspective. Requirements are derived from supply chain stakeholders and translated into vehicle-based services and vehicle components.

Keywords: design methods, design research, new product development

1. Introduction

Accessibility is people's potential to interact and exchange with services. (Hansen, 1959). High geographic impedance between both reduces spatial accessibility and requires vehicle-based transportation of people to mostly stationary services.

This is particularly the case in rural sub-Saharan Africa (SSA), where geographic impedances pose considerable challenges in the form of a lack of access to services since these are often scattered across vast areas with insufficient infrastructure to cost-effectively access them (Starkey, 2007). Healthcare exemplifies this difficulty. Ambulatory services based on special-purpose vehicles have been implemented around the world to increase spatial accessibility from the supply side (USAID, 2020; Tata Trusts, 2020). In the United States, more than 1,500 mobile health clinics are operated and offer a wide range of health-related services (Hill et al., 2014). Implementing services based on vehicles instead of building necessary stationary infrastructure can produce optimal economic solutions (Yücel et al., 2020). The vehicle, the design of its body, and all its mechatronic functions are geared towards a mobile service delivery that often includes many stakeholders. There is a variety of vehicles that can increase spatial accessibility, including mobile vaccination facilities, food trucks, mobile cold storage, rolling libraries, and so on. We classify these offerings as Vehicle-based Services (VbS). VbS are services wherein the involvement of a vehicle is crucial to value delivery. This can refer to either the vehicle's offered services as a primary function or the contents of the vehicle's delivery and subsequent value propositions, the latter of which occurs when the mobility of a service serves as a secondary function (Mahut et al., 2016).

Consequently, the required engineering process for the package design of such special-purpose vehicles differs from that of conventional passenger cars in two regards. First, additional components like a cooling aggregate, front wing, hydraulic appliances, special transport compartments, or additional energy sources might be needed to deliver the service value. This can be related to the development of Product-Service Systems. Second, a vehicle design based on spatial accessibility

needs is highly contextual (Ahuja and Tiwari, 2021), and the supply of services in a region hinges on a network of multiple stakeholders geared towards customers' needs. The particular context of SSA demands a holistic approach that acknowledges unique existing structures (Baltacioglu et al., 2007).
To cater to this increased complexity in the requirement engineering of special-purpose vehicles, we propose a novel design approach for vehicle package design and component selection that utilizes a supply chain perspective and ultimately considers vehicles as a platform for VbS.

2. From supply chain stakeholder to service-based vehicle design

The context in which goods, services, and information flow from the earliest supplier to the end user can be understood as a supply chain (Baltacioglu et al., 2007). For strategic management scholars, supply chain theory is concerned with understanding underlying business processes, finding opportunities for improving competitiveness, and modelling alternative configurations (Huan et al., 2004). As a tool to comprehensively illustrate this theoretical construct, supply chain maps present geographic information, financial flows, and items exchanged between stakeholders (Farris, 2010). To identify and describe all relevant stakeholders, so-called snowball-sampling is a practical approach where interviewing obvious stakeholders leads to more specific actors (Reed et al., 2009; Bianchi and Kossoudji, 2001).

2.1. Customer-oriented product design

Throughout this next section, relevant existing frameworks for designing products based on customer input are reviewed. Most contemporary frameworks define customers' needs as the starting point for all activities (Christensen et al., 2016; Hankammer et al., 2019).
The Jobs-to-be-Done (JTBD) approach zooms into the job customers are trying to accomplish when they choose to purchase certain products or services. JTBD offers solution-independent insight into customer needs, allowing developers to design more suitable and effective products (Christensen et al., 2016).
Outcome-Driven Innovation (ODI) is a method created to better implement the JTBD approach. Designed to identify and prioritize opportunities for improvement in customer jobs (Ulwick, 2016), it systematically maps the steps required to complete said jobs and identifies specific needs for each step. In the ODI framework, needs are expressed as desired outcome statements, which define how customers measure success for each step (Lucassen et al., 2018; Ulwick, 2016). This structure makes eliciting customer needs easier and significantly increases the likelihood of identifying their wants while avoiding discord and redundancies. These outcome statements are then be prioritized to identify the best opportunities for innovators to pursue.
Requirement Engineering (RE), which aims to systematically identify the requirements to a product or service, ensures that each of these are correctly defined (Berkovich et al., 2011). Sources for requirements can include customers (Coughlan and Macredie, 2002; Berkovich et al., 2009; Berkovich et al., 2011), their supply chain processes (Berkovich et al., 2011), the target environment and available technologies (Broy et al., 2007), or knowledge of existing systems and regulations (Berkovich et al., 2011). In goal-driven RE, goals are elicited from customers and requirements are deduced from these goals (van Lamsweerde, 2001; van Lamsweerde et al., 1998).
Quality Function Deployment (QFD) uses a series of matrices to implement the Voice of the Customer across all functions of the company (Griffin and Hauser, 1993). Each matrix compares what should be achieved with how it should be achieved. The 'how' of each matrix becomes the 'what' of the subsequent matrix (Bahill and Chapman, 1993; Karsak et al., 2003). Thus, the design requirements are translated into part requirements, which in turn are translated into manufacturing requirements, and then into requirements for day-to-day operations (Karsak et al., 2003).
Service design approaches contain relevant methodologies for designing products as delivery systems for services or as part of Product-Service Systems. Service Engineering is a model for service and Product-Service Systems design. It finds its basis in examining service processes and customer requirements (Sakao and Shimomura, 2007). Its process revolves around, first, understanding users and identifying their key indicators for service success, and, based on these findings, detecting requirements for a service and the related products (Sakao and Shimomura, 2007).

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Cavalieri and Pezzotta (2012) point out that QFD is a popular and valuable tool for Service Engineering, especially in the requirements phases as it is used "to translate customer requirements into engineering characteristics in product or service design, to measure the contributions of new service ideas to strategic service objectives and to detect gaps in the existing portfolio and to design a service that meets customer's needs" (Cavalieri and Pezzotta, 2012, p. 284).

2.2. Vehicle concept development

In the automotive industry, customer requirements are translated into technical specifications for vehicle components. The volumetric arrangement and dimensioning of these components composes the vehicle package design (Nicoletti et al., 2020). Common passenger cars mainly serve customers' need for convenient personal mobility from the driver's perspective. Their package design consequently consists of mostly driving-related components within assemblies like the drive train and chassis. Thus, the concept of passenger vehicles as Product-Service Systems is most often limited to add-on services that simplify the usage of these core components and ensure their functionality across the vehicle's lifecycle. Examples include maintenance services or financing services like leasing or renting (Mahut et al., 2016). In contrast, there are relatively little non-driving related components, like in-car entertainment systems, and these tend to be limited in size and capacity. Nevertheless, recent research on autonomous vehicle concepts for passenger transportation highlights the growing importance secondary functions related to work and entertainment are taking for car riders (Schockenhoff, 2020).

For commercial vehicles—particularly mobile working machines—this importance is rooted in non-driving functions like pumping, drilling, cooling, or lifting (Geimer and Pohlandt, 2014). Whereas development processes for passenger cars have been formalized, commercial vehicle design, and by extension the design of special-purpose vehicles like mobile health facilities, is a topic that has been deemed irrelevant to academic research so far (Kreimeyer et al., 2016) which might be due to the fact that manufacturers have relatively low production volumes (Nicoletti et al., 2020). Equipment and superstructure development is left to small- and medium-sized manufacturers. Despite this, a formalized design process could be advantageous (Kang et al., 2014), especially when considering the range of possible vehicle concepts based on VbS.

For passenger cars, a framework for automotive services systems from a business model perspective was introduced by Grieger and Ludwig in 2019. This framework investigates the economic potential of services focused on cars while also considering the customer as a value-creating stakeholder within the system. While this perspective does not provide guidance on vehicle package design as such, it does state which aspects have to be taken into account when developing a business model for automotive service systems. The literature has yet to establish a similar perspective on VbS development for commercial vehicles.

2.3. Supply chains and a new perspective on product design

Spatial accessibility is an ongoing challenge in many regions globally. Vehicular capabilities go beyond increasing spatial accessibility by transporting people to the desired access points. Their capabilities act as platforms for services. To develop suitable VbS and vehicles capable of delivering these, a holistic perspective on access needs specific to certain regions is necessary. Supply chain theory aims to identify and understand stakeholder interrelations. Product and service development literature proposes tools to translate customer needs into design requirements. In the next section, we outline a novel framework that applies customer-focused development methods to supply chain stakeholders to identify accessibility-increasing services for SSA and to design corresponding vehicles as service delivery systems.

3. Design of Vehicle-based Service Components

Situational Method Engineering proposes to "construct optimized methods for every systems analysis and design situation, by reusing parts, the so-called method fragments, of existing established methods" (van de Weerd and Brinkkemper, 2009, p. 35). Relevant literature with candidate methods

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have been introduced in section two. Our framework consists of four stages: Landscaping, Stakeholder Needs Analysis, Translation, and Identification of Synergies and Conflicts. It finds conceptual service ideas from supply chain stakeholders. These are subsequently translated into vehicle components for an early package design, with an initial assessment of synergies and conflicts. Emphasis is given here to a continuous methodological pipeline and not to a comprehensive service design. This is done under the hypothesis that while the initial component selection will not change, dimensions will. Elaborate service design can happen at a later stage with service blueprinting or similar tools.

3.1. Landscaping

The purpose of this first stage is to gain an overview of the context that is to be investigated. The only initial input that is required is a definition of the context under investigation. Landscaping entails two steps: Stakeholder identification and supply chain mapping.

For stakeholder identification, we adopt the snowball sampling technique, as suggested in Stakeholder Analysis literature (Bianchi & Kossoudji, 2001; Reed et al., 2009; Pouloudi & Whitley, 1997). Secondary research is conducted first to help designers brainstorm an initial list of stakeholders. Sources may include, depending on the context, published papers, reports from aid organizations, NGOs, or governments. Next, in-depth interviews with all stakeholders on the initial list are conducted. Stakeholders are queried about their role and their activities within the context at hand. These activities should be described in as much depth as possible, as this will contribute to understanding stakeholders' motives, which are crucial to later stages of this framework. Additionally, the interviewees are asked to identify stakeholders which may be unknown to the questionnaire team. After each interview, the list of stakeholders is updated. All newly identified stakeholders are also interviewed in the manner described above. This iterative process of interviewing stakeholders to identify new stakeholders is considered to be complete when all stakeholders on the list have been interviewed and no additional stakeholders could be identified. However, should the snowballing process not come to such a natural conclusion, the designers may establish well-founded and well-documented stopping criteria. Such criteria could include demographic factors such as age or geographic factors such as boundaries (Reed et al., 2009).

The second step, mapping, is meant to create a visual overview of the previous step's results. It is at this juncture of the framework that the research context is defined as a chain. The flows to be included in this chain are those of physical goods and/or people, services, funds, and information. The conventions established by Deutsche Gesellschaft für Zusammenarbeit (GIZ) for value chain mapping have been chosen for usage within this framework. As part of these mapping conventions, stakeholders are classified into main stakeholders and supporting stakeholders, further focusing the remaining analyses (GIZ, 2018).

3.2. Stakeholder Needs Analysis

The aim of this stage is to fully understand all stakeholders identified during the previous stage and to grasp which of their needs may be addressed through VbS. Considering the relevant steps of ODI and Service Engineering, this stage of the framework adopts four steps: Discovering Jobs-to-be-Done (JTBD), identifying stakeholder needs, translating needs into desired outcomes, and prioritizing desired outcomes.

First, the jobs a stakeholder is trying to get done in the context of the chain are identified. This can be deduced from (1) the activities that the stakeholder is involved in within the context of the chain and (2) the interviews conducted during the previous stage. JTBDs may also be described as a stakeholder's goal when participating in the chain or their reasons for doing so. Once jobs are identified, steps that the stakeholder must go through in order to get the job done are listed one by one in a manner that is solution-independent.

For the second step, the framework differentiates between situations where primary data can be acquired with reasonable effort and situations where this is not possible. When primary data can be gathered, interactions with as many stakeholder representatives as deemed appropriate should be sought, with the goal of identifying stakeholders' needs at each job step. Such interactions can take the form of 1:1 interviews or workshops, during which several stakeholders can describe their needs and

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pain points. If no or little primary data can be gathered, stakeholder personas should be created using collected secondary data. Once the needs for each step of all stakeholder's jobs have been gathered, these are translated into desired outcomes.

Outcome Statements (OS) are statements detailing how the stakeholder measures success at each step of the job. An OS as used in this framework is made up of three parts: Direction of improvement, unit of measure, and the object of control. Examples are included in the upcoming case study. Thus, at the end of this phase, at least one OS defining a stakeholder's success when completing each individual job step should be established. Each OS signifies the importance to the stakeholder. The aim is to ascribe each OS an Importance Weight (IW) from 1 to 10, with 1 being of low importance and 10 high importance to the stakeholder. If an appropriate number of representatives of a stakeholder type are reachable for conversation, surveys or interviews are preferred. If this is not feasible, the personas are utilized. In cases of insufficient access to stakeholders, design teams can conduct a pairwise comparison between OS in accordance with Knorr and Friedrich (2016), which requires using the created personas to empathize with the stakeholder to score the importance of each OS. OS with an Importance Weight of 0 should not move onto the following stage. In cases where the number of OS to be addressed is too high, the threshold for Importance Weights may be set to a higher standard at the discretion of the team.

3.3. Translation

During the Translation-stage, potential service concepts able to help stakeholders get their jobs done are identified. As this framework is explicitly aimed at the design of vehicle packages based on the needs of supply chain stakeholders, the solutions to these needs must be framed as VbS. Services are framed as a solution to stakeholders' needs at different job steps, delivered through a vehicle, including the required vehicle components. Any further elaboration of the service concept must happen at a later stage.

To translate jobs, job steps, and desired outcomes into VbS, a hierarchy tree is established. This tree is created separately for each stakeholder type.

The JTBD identified during the previous stage represents the first level of the tree. The next level should be filled with the steps necessary to get each job done. The third level of the tree should represent the VbS that could potentially help the stakeholder address one or multiple job steps. VbS should be kept general at this stage and represent a service that a provider could potentially offer to help the stakeholder with one or multiple job steps. In the case study contained in section 3.5, one possible VbS is "Cocoa Transportation Service". The next level represents the OS associated with all steps addressed by the service. One OS associated with the job steps that "Cocoa Transportation Service" addresses is "increase certainty about weight of cocoa sold". On the fifth level of the tree, design requirements associated with each outcome statement are listed. One possible corresponding design requirement to the previously mentioned OS is "capability to weigh cocoa". Finally, components or vehicle properties needed to fulfil the design requirements represent the last level of this VbS-Tree. Hard- and software components are considered. One necessary component to realize the described design requirement is a scale that is integrated into the vehicle.

The lists of possible VbS, OS, design requirements, and components is merged across stakeholders. If two or more stakeholders require the same VbS, the service can be merged into one. In these cases, all design requirements and corresponding components can also be added while duplicates are eliminated. All addressed OS from all stakeholders requiring the service should be added as well. Where duplicates occur, the IW of the OS are summed-up. Simple summation of IW is deemed appropriate by the authors, as the final goal of this IW scoring is to prioritize services and, thus, prioritize vehicle components for package design. It is justified to significantly increase the importance of a service and the corresponding vehicle components when the service delivers value to several stakeholders. Such an increase is achieved by adding the IW of OS in cases where two or more stakeholders desire the same outcome.

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3.4. Identification of synergies and conflicts

This stage helps designers discover synergistic VbS. Preliminary indicators are established on the stakeholder desirability and on the technical feasibility of the identified VbS. By doing so, VbS and consequently vehicle components are prioritized for package design. This is necessary as vehicle resources such as built space, available energy, and admissible weight are limited. Conflicts and synergies between all services and all desired outcomes are examined so as to fall within the confines of possible resources.

Second, synergies between the VbS themselves are assessed by analysing which services share components, resulting in a synergy score able to positively contribute towards a feasibility analysis. The VbS that address either multiple jobs and desired outcomes and / or address the jobs and desired outcomes of multiple stakeholders are identified here. Considerations regarding which services may potentially negatively affect jobs or outcomes is also done here. Based on these, a first desirability score (DS) for each service is established. Like in other common QFD practices, an "Outcome-Service Matrix" is created. The list of weighted OS represents the rows of this matrix. The complete list of VbS emerging from the previous stage represents the columns. Scores are assigned to each cell depending on whether a VbS addresses an OS completely (add IW of OS), affects it positively (add one-third of IW of corresponding OS), or whether it works against the achievement of the OS (subtract half of the IW of the OS). The sum of all cells in a column represents the DS of the VbS heading that column.

Synergies between VbS are identified at the component level. A synergy here is defined as two VbS sharing one or multiple components. If VbS that are to be implemented in the future share components with VbS that have already been implemented, adding these new services to the same vehicle platform will be easier and less costly than in a case where no synergies exist seeing as some of the required components have already been installed. To discover and score these synergies, another QFD-based matrix should be created, named "VbS-Component Matrix". As the name indicates, VbS represent the rows of the matrix and components represent the columns. To fill the VbS-Component Matrix, the designer enters 1 for each component that is necessary to implement the service in the corresponding cell. A synergy score (SS) is introduced for each service by assessing the number of services that require a component. Based on this, services requiring common components receive higher synergy scores.

To merge the results for multiple chains analysed according to this framework, the two final scores for desirability and synergy must be applied across chains. Therefore, the previous stage must be repeated, this time using a list of OS applicable across chains that includes the list of weighted OS used for the Translation-stage of each chain. The rules for merging the lists of OS remain the same as during the Translation-stage, meaning that the IW of duplicate OS are added-up again. Then, the Outcome-Service Matrix is established once more using the large list of OS and a list of all VbS, with each service only represented once. Similarly, the VbS-Component Matrix is set up again using the full list of VbS and a list of components collected from all chains. This is so the two scores can be calculated across chains.

3.5. Case study: Cocoa supply chain in Côte d'Ivoire

The authors are members of the aCar Mobility Research Project, which implements a special-purpose electric vehicle (aCar) within SSA in order to increase rural populations' spatial access to services. One location of implementation is Côte d'Ivoire. Our focus is the country's cacao supply chain, which accounts for 28% of export earnings and contributes to 10% of the country's GDP (OEC, 2021). Consequently, cocoa provides a livelihood for more than one million smallholder farmers (FAO, 2017). The national cocoa supply chain starts with small and rural farms spread across the country and ends at the main export harbour in San Pedro with three other main stakeholders involved. (Figure 1). exemplifies the application of this methodology during and after a field research project in Côte d'Ivoire in July 2021.

During Landscaping, four essential supply chain stakeholders were identified from literature, where three (excl. *Exporter*) could be interviewed in the Yamoussoukro District. In total, six in-depth interviews with cacao farmers, two transport operators, and three representatives from local cacao

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cooperatives were conducted by a research team including the first author, confirming the initial set of cacao supply chain stakeholders. For the framework's second step, a two-day workshop with 20 participants representing the aforementioned groups was held. The participants were encouraged to depict their activities (i.e. cultivation of farm land) along the supply chain in as a detailed manner as possible. Based on clustered activities, JTBD were derived and visually represented within the workshop space. The research team facilitating the workshop then focused on critically reflecting upon the challenges faced by participants during the execution of their activities. The challenges were prioritized by the participants according to their perceived severeness and translated into needs. The workshop results were then compared to the findings from literature and 15 OS were derived by the authors (i.e. OS_13: Objective of control = certainty about cacao weight on site; Direction of improvement = increase certainty; Unit of measure = weight of cacao; IW = 10). The fact that many cacao farmers lack access to agricultural inputs during farming to increase their productivity resulted in a conceptual VbS design of a "Farming input delivery service" (DS = 12). To perform this service, the vehicle requires a set of components to safely maneuver the load on non-existent, deteriorating, and often flooded roads. Amongst others, this includes a front winch (SS = 5) to be leveraged during rain season. In this manner, three more VbS were conceptually developed (Road and field clearing service, DS = 40; Farming service, DS = 2; Cacao transport service, DS = 92). Required vehicles components for these VbS range from a loading bay with mounting hinges (SS = 10,5) to Global System for Mobile Communications (GSM) internet modules (SS = 5) with no direct conflicts.
The research team will implement two functioning prototypes for validation of this framework by 2023 in collaboration with the GIZ and local research partners in Côte d'Ivoire. VbS components will be mounted to the aCar and respective VbS will be offered to the cooperative's members. Based on demand frequency and a relative willingness to pay per VbS, the DS ranking can be evaluated. The validity of SS will be assessed by successfully performing VbS combinations on one vehicle.
A similar case study has been conducted in Ethiopia on the rural healthcare supply chain but implementation have been seized due to the armed conflict starting in 2021.

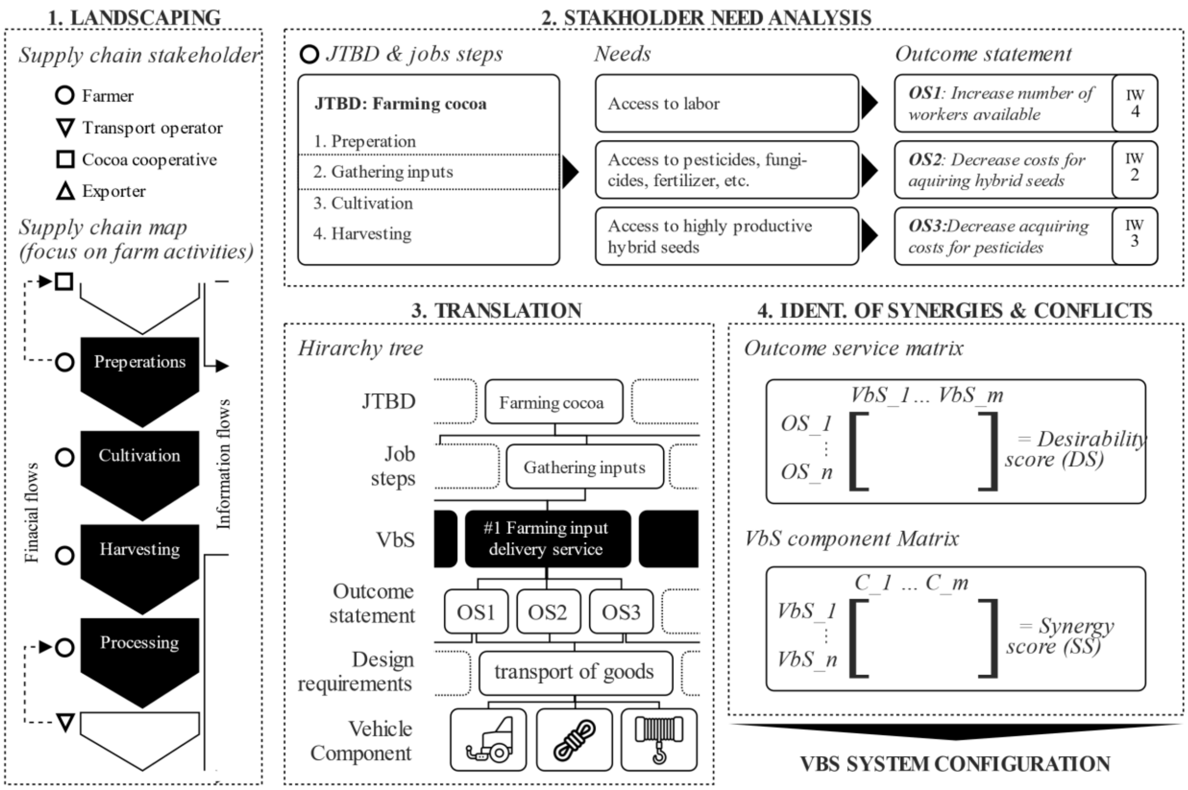

Figure 1. Case study: cocoa supply chain, côte d'Ivoire

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4. Discussion & conclusion

Spatial accessibility is a complex issue largely shaped by individuals' desire to overcome physical separation (Hansen, 1959). Vehicles can be mobile platforms for services of any kind (Grieger and Ludwig, 2019), capable of addressing people's demand for access where supply is scarce. In this paper, we have argued in favour of a new approach to design vehicles that deliver these VbS. Our contribution can be perceived as a conceptual framework to comprehensively guide designers towards a vehicle design capable of delivering VbS that enhance supply chain operations. Accounting for the potential lack of access to stakeholders when conducting research in SSA, the framework works when primary data is unavailable too. The results generated can be used for the assessment of early package designs of special-purpose vehicles. A defined set of decision variables, namely desirability and synergy scores, aims to objectivize the component selection process during requirement engineering. Concerns surrounding the prioritization of some stakeholders' needs over those of others have not been addressed. Considerations about profitability and technical viability are mainly neglected. While the case study approach provides some internal validity (Gerring, 2006), this framework remains to be externally validated.

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