OPEN MOBILITY SYSTEM

OMOS

“The joint journey towards seamless mobility”

CONCEPT PAPER

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We are grateful for all the highly valuable input, challenging discussions and support from companies and institutions ranging from energy and mobility corporates and blockchain start-ups to scientific institutions.

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THE OPEN MOBILITY SYSTEM - EXECUTIVE SUMMARY

Digitalization has redefined many aspects of our daily lives and continues to do so. Increasingly, it is also redefining how we perceive and experience mobility and transportation. With this paper, we wish to offer a way of capitalizing on this transformation. It is our shared opinion that, as of today, we will need to build a cooperative new digital mobility infrastructure beyond company borders and across established industries. We thus extend an invitation to contributors from around the globe - companies, scientific and governmental institutions, and commuters - to join us and shape this digital mobility infrastructure together.

Customers will seek a seamless mobility experience

As we see it, our future mobility will largely be predicated on one basic desire shared by commuters and passengers the world over: To get from their preferred point of origin to any desired destination in a seamless way. Accordingly, we have developed and are now pleased to introduce our concept for **Seamless Mobility as a Service (Seamless MaaS)**.

Seamless MaaS goes far beyond existing concepts of intermodal transportation and flashy routing apps. It is about experiencing affordable, green, on-demand mobility, which spares passengers the hassle of owning a car, the cost of upkeep or even the nuisance of refueling and charging. Bills will be highly transparent and settled automatically, no matter how many different mobility services or transport modes passengers use along the journey.

Seamless MaaS will embed all modes of transport, ranging from cars and trains to bikes and scooters. It will include autonomous cars that transact and communicate with their passengers, each other, and countless other IoT devices in our cities, ranging from electric charging devices to parking lots and toll stations. With Seamless MaaS, we can ultimately shape a highly interconnected machine economy where transport modes own and manage themselves.

We are thus convinced that Seamless MaaS will have a comprehensive and positive impact on society as much as on the environment: significant decrease in CO_2 and other emissions due to higher efficiency of all mobility assets, more quality time to spend with family and friends, and greater freedom in choosing where to live, to name but a few.

Seamless Mobility as a Service requires new levels of organizational cooperation and a new digital infrastructure layer

This Seamless MaaS future will demand significantly more cooperation between companies and industries as well as a new digital infrastructure layer. To identify the best solutions to these challenges, we reviewed potential cooperation models and assessed various technical solutions that would not only allow but indeed encourage cross-company and cross-industry cooperation. On the basis of this analysis, we expect to see the emergence of an ecosystem of interconnected mobility assets and service offerings built around one of two fundamentally different paradigms: Either a centralized platform, presumably on a global scale, or an open and fully distributed system.

The future will be open and distributed

In principle, both centralized platforms and open systems allow for a very low level of transaction cost while minimizing interoperability issues on the technical and also the organizational level. Nevertheless, we believe that an open and distributed system will better serve end-customers and mobility companies:

- **An open system will not create lock-in effects and information monopolies.** Rather, it encourages creative and fair competition within a communal and democratically governed digital transaction infrastructure.

- **An open system will allow a high level of data sovereignty for customers and companies.** It facilitates secure, controlled, use-case specific, and real-time data sharing.

- **An open system encourages participants to co-create** with one another and thus to leverage the expertise and skills of people and companies from around the globe. It does not evolve in the minds of a select few developers within a closed platform ecosystem.

Blockchain technology can enable an open Seamless Mobility as a Service system

Based on prior experience with blockchain technology, we are convinced that blockchain and its technological successors can facilitate the development of an open Seamless MaaS system. They allow us to collectively usher in a new age of secure cooperation and transaction, and they do so without the least requirement of personal trust. For the first time in the history of mobility, we possess the technological potential to build a truly distributed and open mobility system providing Seamless MaaS.

The Open Mobility System journey

Together with partners from various industries in various parts of the world, we are now striving to set up the “Open Mobility System - OMOS”. We envisage OMOS as a blockchain-based system that creates new ways of transacting and data sharing among all participating partners. OMOS adheres to the following essential values: openness, inclusiveness, transparency, equality, and non-profit orientation. It shall afford all partners a base on which to build business applications that offer customers the seamless MaaS experience they are seeking.

So far, we are merely at the beginning of the OMOS journey. Its advancement depends not only on a shift in mindsets around co-operation but also on the successful negotiation of various technological challenges. We therefore invite partners to embark on this collective journey with us. Starting now, we are setting up the first Open Mobility System and jointly working towards the best technological solution.

Please find more information on: www.omos.io

OUR VISION OF THE FUTURE: SEAMLESS MOBILITY AS A SERVICE

SEAMLESS MOBILITY IS RAPIDLY BECOMING THE PREFERRED CUSTOMER EXPERIENCE

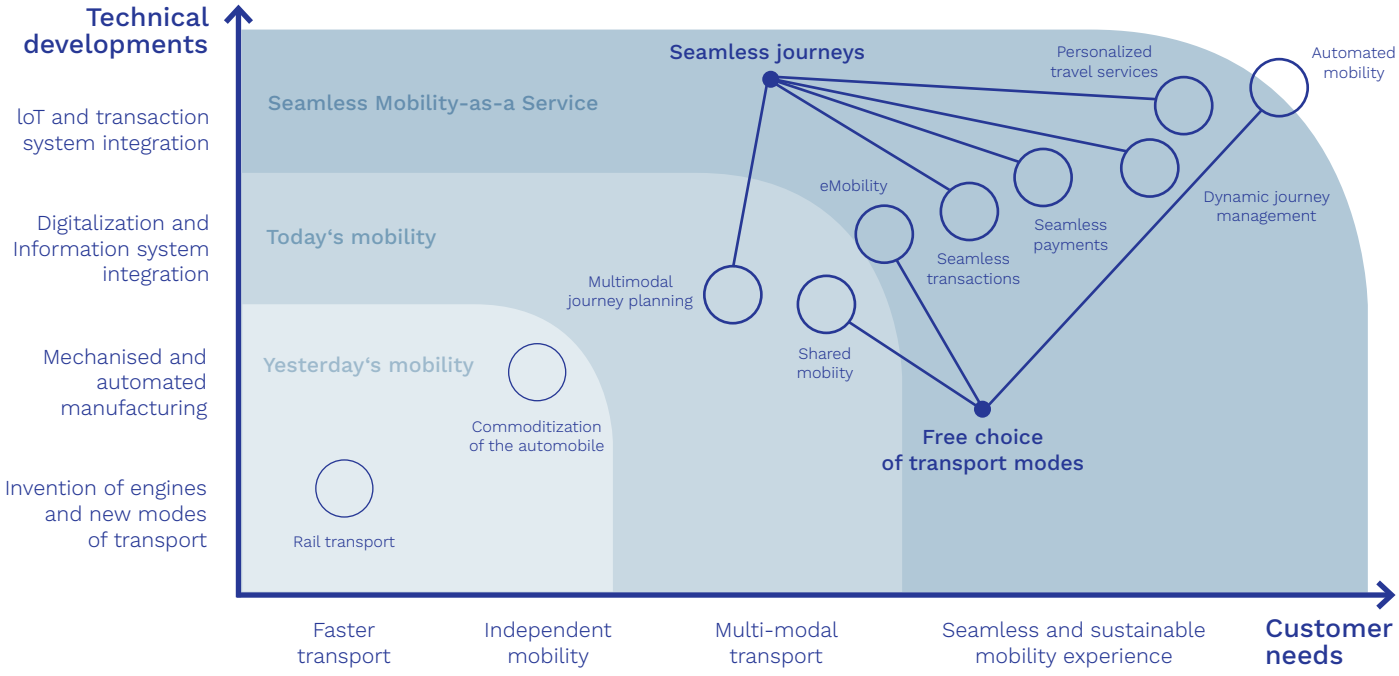
Today's mobility and transportation systems have been shaped by evolving customer needs. In the 19th century, the pursuit of more efficient and faster transport led to the invention of trains and public urban transport systems. In the course of the 20th century, we then saw an entire industry emerge around private automobiles, as they became synonymous with independence and freedom of movement [1]. For millennials, however, car ownership is no longer the same status symbol and thus far less of a driving factor in their transportation choices [2]. Unlike their parents and grandparents, they take a more pragmatic approach and increasingly prefer to combine multiple modes of transport dynamically so as to best match their varying mobility needs [3].

Fueled by rapidly progressing digitalization, new sharing models such as B2C and P2P car sharing or ride hailing are emerging. Especially ride hailing platforms like Uber and Lyft, where car owners can offer private taxi-services, have helped car owners in (partially) covering their car's operational expenses. They have also improved car utilization rates by more than 30% over traditional taxi services [4].

At the same time, mobility providers have been introducing innovative functions like end-to-end journey planning, and digitalized booking, ticketing, billing and payment. However, these services remain highly fragmented, and due to the lack of effective technology for IoT transactions, integrated user journeys are not yet viable.

Seamless Mobility as a Service (Seamless MaaS) aims to remedy this fragmentation. It represents the idea that customers can journey from point A to point B with zero hassle, using the most efficient combination of transport modes available, yet without having to own any of them. Seamless MaaS promises customers accessible, affordable and personalized solutions that best suit their individual mobility preferences.

Figure 1: The evolution of Seamless Mobility as a Service [5,6,7]



INFO

With B2C car sharing, customers gain access to corporate fleets usually offered in restricted geographical regions and with a variety of tariffs. Prominent examples include Daimler's Car2Go or the BMW/Sixt joint venture DriveNow. With P2P car sharing, consumers rent out their vehicles to others for a short time (see, for instance, Drivy and Turo).

Table 1: Customer solutions enabling Seamless Mobility as a Service [5,6,7]

	Customer solution	Perceived customer benefits
Seamless journeys	Multimodal journey planning	Free multimodal trip configuration according to personal preferences
	Seamless transactions (“Open access”)	On-demand mobility asset access with multiple forms of identification (such as smartphones, smartwatches and physical IDs)
	Seamless payments (“Split the bill”)	Automated payment for all travel legs and mobility services based on the customer‘s preferred payment options such as pay-as-you-go or subscrpition models
	Dynamic journey management	Real-time updates and itinerary adjustments in response to changing journey parameters, i.e. detours or delays
	Personalised travel services	Add-on services to enrich the mobility experience, incl. proactive itinerary suggestions based on learned customer preferences
Free choice of transport modes	eMobility	Electric mobility options that meet green customer preferences
	Shared mobility (B2C and P2P)	Significantly more mobility options, increased availability of transport and additional revenue sources for sharing privately owned mobility assets
	Automated mobility	Self-operated mobility options such as automated public transport and self-driving cars on almost all itineraries

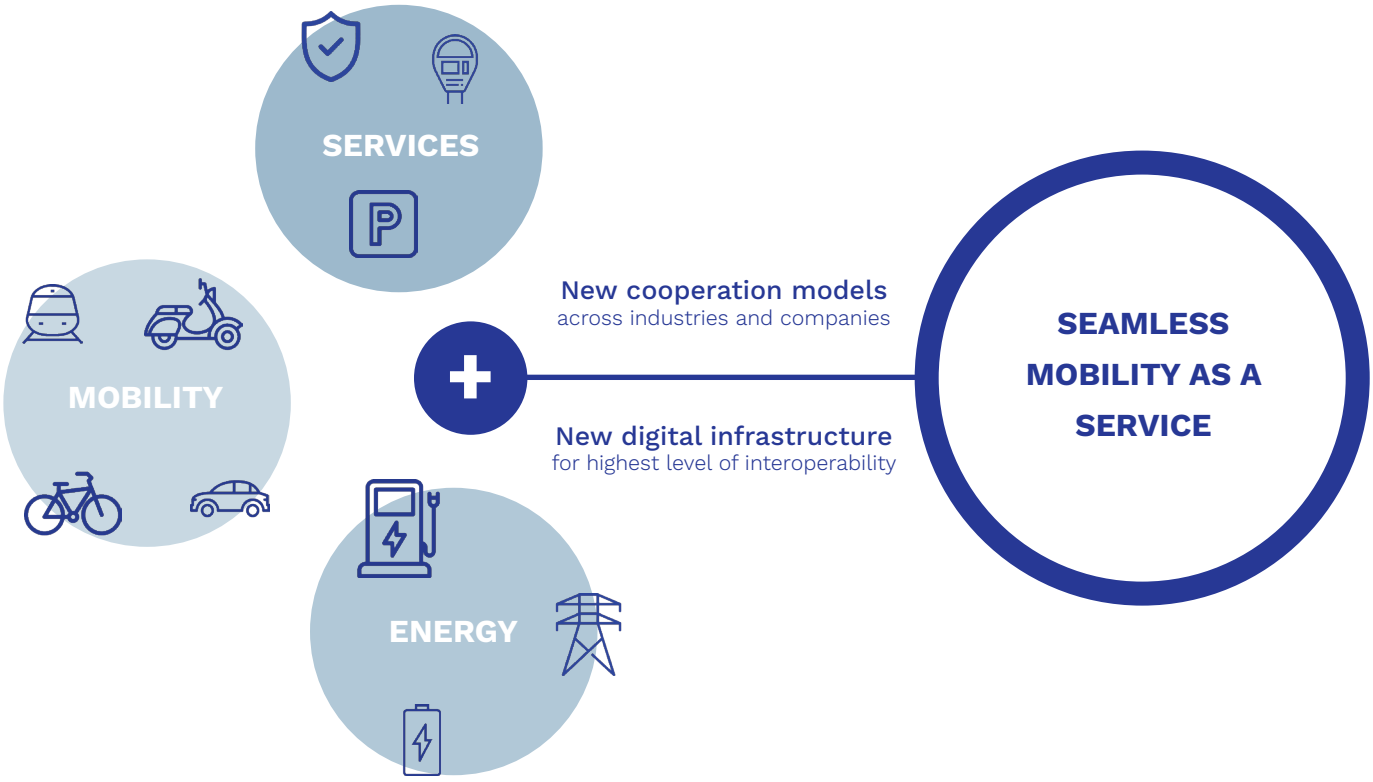
Mobility customers will benefit in multiple ways. Not only will they be able to use and pay for a large range of mobility assets via a single app on their smartphone or smartwatch. They will also be notified in real-time of delays and alternative itineraries. Personalized travel services can further enrich the mobility experience, for instance by offering individualized routes from learned customer preferences or life-style information such as the social media feed of fellow travelers. Ultimately, it seems to be only a matter of time before self-driving vehicles and the experiences gained by enlarging and analyzing a shared data pool will afford us the opportunity of fully autonomous transport. Independent mobility will then be accessible to all passengers and especially to previously rather disenfranchised customer segments, such as the elderly, children, and the disabled. What is more, fully autonomous vehicles will be connected in real-time to the surrounding infrastructure of traffic sensors, parking lots, charging poles, toll stations, and other modes of transport, thus enabling large scale traffic optimization and considerable reductions of air pollution as well as energy and space consumption. In the long run, a fully integrated and automated traffic system might also render classic ownership models obsolete and facilitate a machine economy in which autonomous mobility assets such as motorized vehicles and even bicycles are their own owners, generate their own revenues, pay for their own repair and energy needs, and ultimately also settle their own tax liabilities.

Mobility providers who facilitate these solutions will gain unprecedented access to customer information, while, at the same time, preserving the individual traveler‘s privacy. This data access will enable almost real-time response to changing customer demand. Bus operators, for instance, will be able to dynamically adapt routes and schedules based on where passengers wish to travel and when they prefer to do so. Rich transport data sets will also allow companies to recognize changing customer needs faster and more reliably – which will ultimately afford them the opportunity to shape the market and tailor innovative, personalized, and marketable offers.

As for private owners and professional operators of mobility assets, they will similarly benefit from seamless MaaS. By sharing their cars, for instance, private users can recover parts of their fixed costs and insurance bills. Professional operators will be able to maximize the use of their mobility assets, while reducing the idle times of vehicles as well as their parking spaces and charging poles, to name just a few of the many benefits. Perhaps the most striking one is that cost allocation is also becoming easier and fairer with innovative payment solutions such as Pay-as-you-go and Pay-per-use. Hence, the global revenue potential of Seamless Mass is estimated to range between $1 trillion to more than $10 trillion by 2030 [8,9].

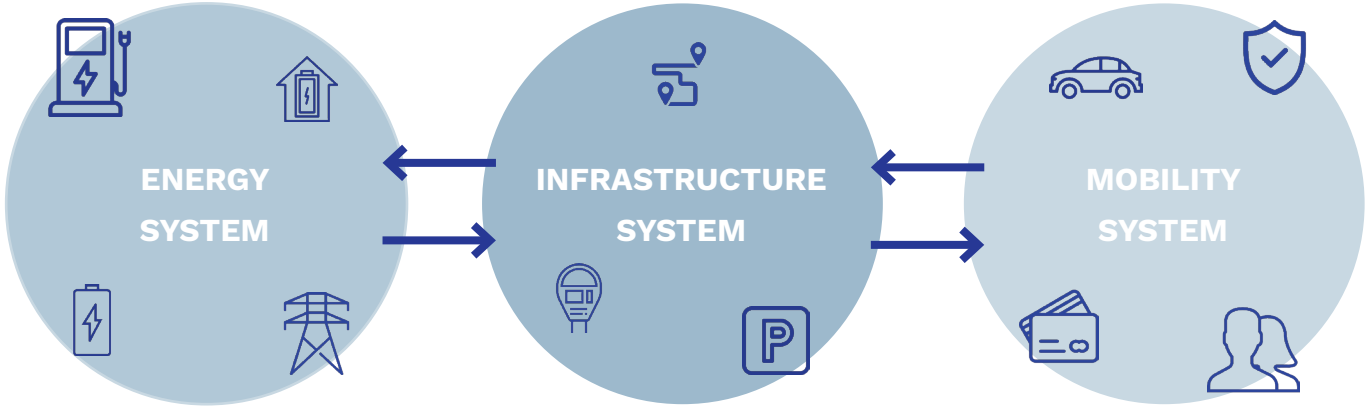
To provide Seamless MaaS, however, current mobility partnerships won’t suffice. Instead, we will need a closely-knit ecosystem of mobility services and assets that can overcome organizational and technological challenges.

Figure 2: Seamless Mobility as a Service requires new cooperation models



The future MaaS ecosystem will need to engage existing and new mobility service providers as well as encourage information sharing and collaboration between competitors and industries. This requires a fundamentally different mindset and a new skill set, not only in companies but also in governmental, regulatory, and scientific institutions. Simply put, it will require new cooperation models. These models will effectively need to ensure that data can be shared freely, yet ownership and sovereignty, especially of valuable and sensitive data, can be preserved at all times. Thus, Seamless MaaS poses a set of technical challenges, as new participants in the mobility ecosystem will need to safely integrate multiple information, transaction, and payment systems. These systems will not only need to be interoperable, they also need to guarantee a fast and stable operation, as well as a high level of data and cyber security.

Figure 3: The current state of IoT -
fragmented centralized platforms that interact via complex interfaces



SEAMLESS MAAS REQUIRES AN OPEN MOBILITY SYSTEM

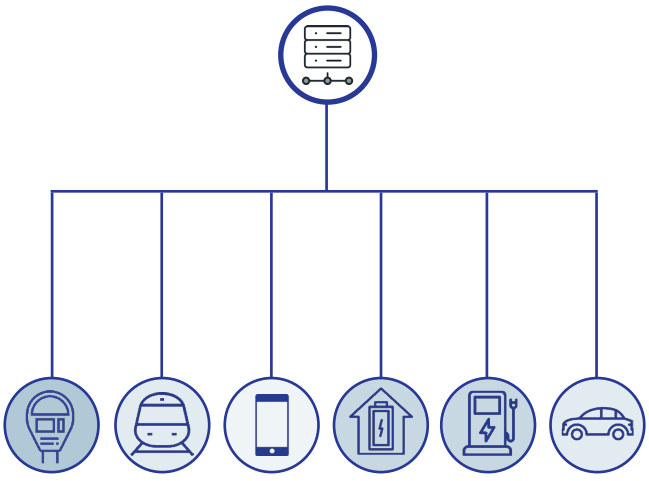
To overcome these challenges, we believe that future seamless MaaS systems will tend towards two options that could meet the dual needs of organisational cooperation and technical interoperability at the lowest transaction costs [10].

1 A fully centralized and closed mobility system in which a single party will provide a global MaaS platform on which all stakeholders can connect.

Closed and centralized platforms are often said to improve user relevance and offer highly customized user experience [11]. Unfortunately, they also pose significantly adverse effects to free market competition. If large enough, the multi-sided platform owner effectively adopts market control and influences cross-competitor competition by dictating access, pricing, technology, and user experience [12,13]. Worse still, the platform model shifts brand equity from the service provider to the aggregating – and user-facing – platform. Centralized platforms are thus often described as ecosystem gatekeepers with the power to shape industry partnerships and collaborative innovation-efforts [14].

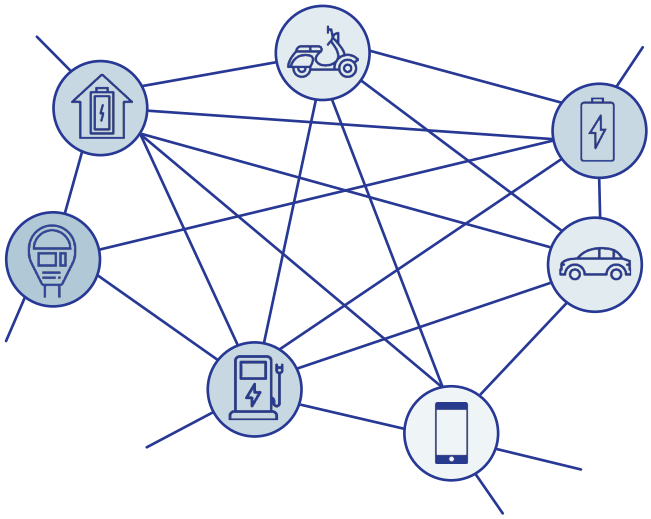
Ultimately, network effects and lock-in effects can lead to a market of competing centralized platforms [15]. This would be toxic for Seamless MaaS, as it requires broad integration, rather than fragmented platforms. Thus, we expect that the centralized platform model would pose significant challenges to a seamless customer journey.

Figure 4: Closed mobility platform



2 A fully decentralized and distributed open system, in which the MaaS ecosystem is owned, governed, and operated democratically by all ecosystem participants.

Figure 5: Decentral & open system



Open and distributed systems represent a more promising approach to mobility service platform design. For one, they are democratically owned, operated, and governed by the system participants. They also act as a common infrastructure, on which participants are free to build and run various business models [16]. Such an open mobility system might appeal to incumbent players, as it allows them to maintain information sovereignty and branding. Likewise, it can incentivize new entrants by virtue of offering every participant the freedom of designing novel products and services without suffering from monopolized pricing and revenue streams [17].

As the system is open and shared, demand for competing systems is effectively eliminated. Participants can freely decide whether or not to share information with other participants. Still the prospect of acquiring and refining customer (preference) profiles by sharing information on customer demand via seamless MaaS is a strong incentive for participants to cooperate. While the shared development might result in more fuzzy design, new entrants can easily participate and add functions that meet the particular needs of their information systems.

Table 2: Comparison of closed mobility platforms and open mobility system in terms of general Seamless MaaS challenges

		Closed mobility platform Third party controlled platform that hosts (brand-agnostic) mobility services	Decentralized open system Common platform with shared ownership, democratic governance and free access
Organizational challenges	Ability to engage both existing and new mobility providers	**Highly unlikely** Mobility providers will be reluctant to work with third party intermediaries who control information, IP and offer-design. This will eliminate brand equity and unilaterally dictate fees	**Highly likely** All participants can choose to maintain various degrees of data sovereignty and control over offer-design, pricing and branding
	Ability to encourage cross-competitor and cross-industry collaboration	**Highly unlikely** All participants are relegated to mere supplier roles. Unified platform standards allow easy integration of cross-industry offerings, yet competing mobility platforms might evolve. The platform owner controls access and might therefore implicitly hinder innovation by cross-industry collaboration	**Likely** The system allows participants to easily interact with each other. Information can be shared with other participants (cross-competitor and cross- industry) if this ads value. As the system is open and shared, demand for competing systems is low
Technical challenges	Ability to integrate multiple systems	**Ambivalent** The platform operator provides powerful and standardized APIs. Systems and use cases not fitting these standardized APIs will be left out	**Likely** Shared governance and democratic development lead to fuzzier APIs yet allow more agile integration of new systems and use cases
	Capability to handle large amounts of data efficiently and securely	**Ambivalent** Centralized systems can process large amounts of data more efficiently. However, the centralized platform presents a single point of failure for data breaches	**Ambivalent** Data processing is less efficient, and the decentralized and distributed nature of the system opens up more vectors for data breaches

Accordingly, we believe that seamless MaaS will demand a distributed open mobility system that provides the necessary connection between all participants, yet does not constrain competition and innovation.

Such a system could:

- **Warrant a high level of data sovereignty**, as companies and customers can freely decide which of their data to share with others

- **Avoid lock-in effects and data monopolies**, instead encouraging creative competition via its open infrastructure

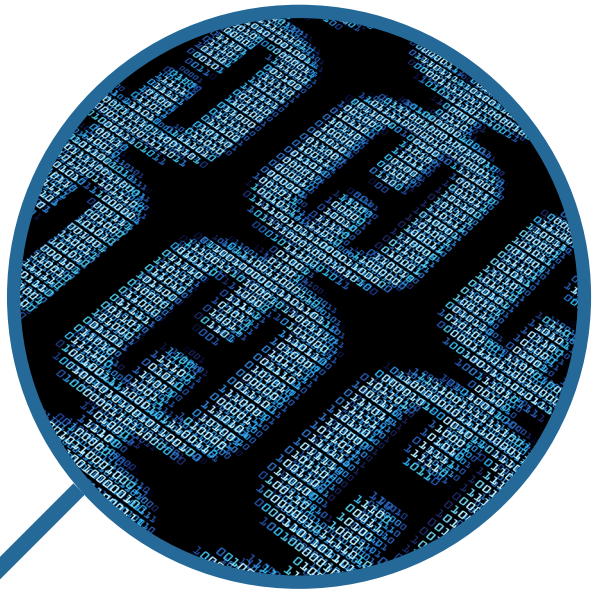
- **Unlock the power to co-create** and leverage the expertise and capabilities of various people and companies around the globe.

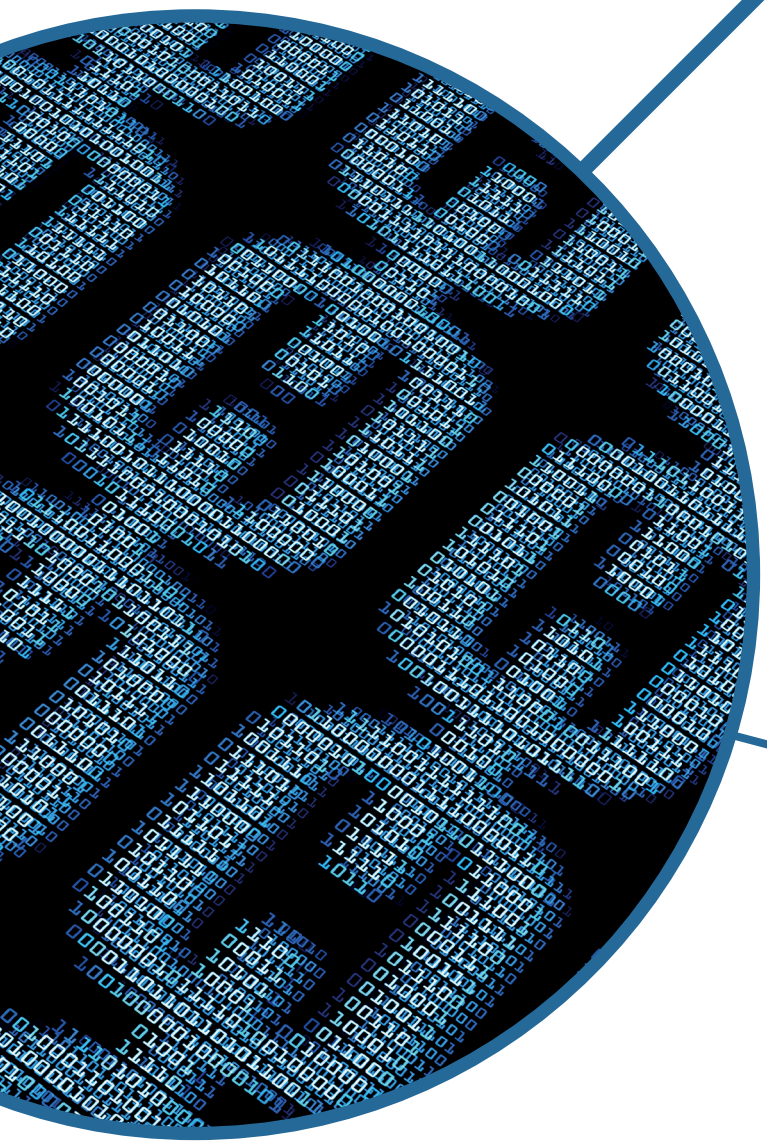
Due to insufficient technology, these advantages have long remained elusive, yet with blockchain technology we now have the technological tools required to finally facilitate an open mobility system.

BLOCKCHAIN: DISTRIBUTED LEDGER TECHNOLOGY FOR A DISTRIBUTED OPEN MOBILITY SYSTEM

BLOCKCHAIN TECHNOLOGY IS MOVING OUT OF BITCOIN'S SHADOW

The first blockchain made its appearance in 2009 as the transaction record keeping technology behind bitcoin, the first decentralized cryptocurrency[18]. It was not until the end of 2013, however, that blockchain technology began to move out of bitcoin's shadow. At this point, investors and software developers had realized that blockchain technology could do way more than merely track transactions. It could also drastically reduce associated costs by eliminating intermediaries. Thus, it became instrumental in building a decentralized system that everyone could join and benefit from [19].

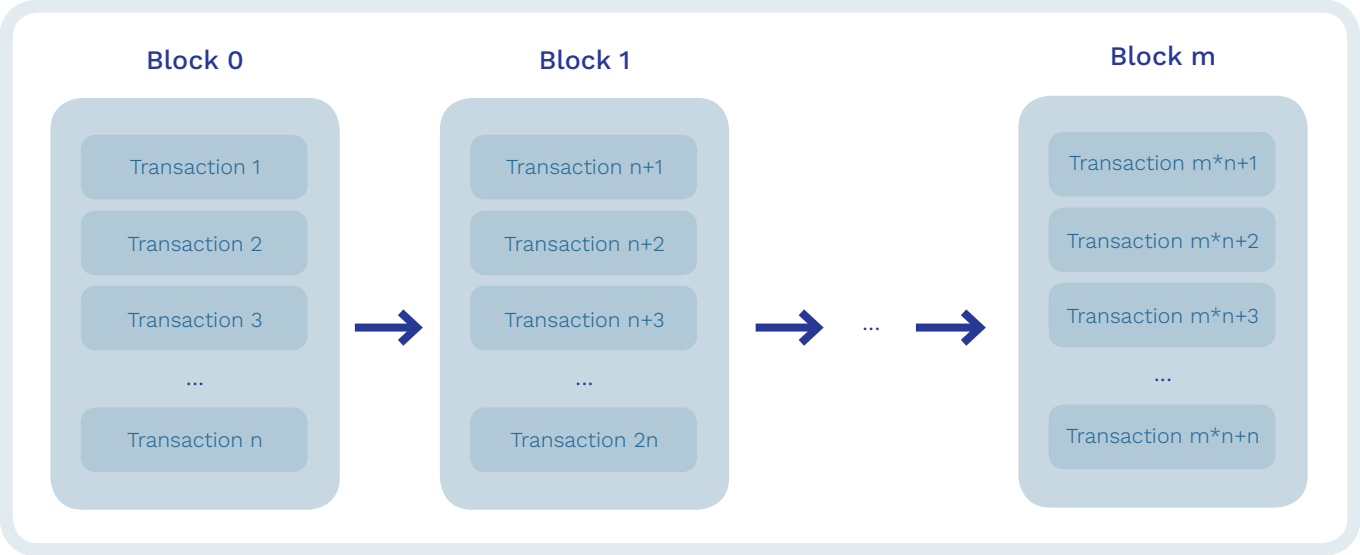




BLOCKCHAINS CRYPTOGRAPHICALLY CONCATENATE INFORMATION ON A DISTRIBUTED DIGITAL LEDGER

Conceptually, blockchains are a new approach to storing and sharing information securely in a distributed network. These chains record information such as IDs, transactions, and small computer programs (so called smart contracts) in a series of concatenated blocks, hence the name blockchain. The resulting chain is distributed to multiple computer nodes in the blockchain network. As new information and new blocks are validated and added, the chain grows in size.

Figure 6: The concatenation of blocks, which include the transaction relevant data.



Blockchain technology is often branded as a form of Distributed Ledger Technology (DLT), yet it is more than a shared record on a distributed network. It adds a high level of information security by cryptographically binding new validated blocks to the existing chain, using so called hashes. In other words, once the information has been stored in a block and this block has been added to the chain, it has become part of a near-tamper-proof record.

Blockchain networks consist of computer nodes that are connected via the internet or other communication networks. Nodes use software known as blockchain clients which perform tasks such as validating and relaying information. Each node has a copy of the blockchain that is downloaded upon joining the network and is constantly synchronised with other nodes to obtain the latest blocks.

BLOCKCHAINS PERMIT DIFFERENT LEVELS OF INFORMATION PRIVACY

Blockchains can implement various levels of information privacy. The most prominent blockchains, such as Bitcoin and Ethereum, are public. Any information stored on them is fully transparent, and any new participant can establish a connection to these networks without being registered or applying for permission to do so.

Table 3: Information privacy options on blockchains

Full transparency on public blockchains	**Partial transparency** on consortium blockchains	**Selected privacy** on blockchains with "transaction privacy" features
Anyone can participate on public blockchains (permissionless participation)	Only vetted and authorized parties can participate (permissioned access)	Selective privacy can be combined with various participation models
Information is transparent to all participants	Transparency extends to all consortium members	Information access can be limited to a select set of participants

Conversely, private blockchains, also known as consortium blockchains or permissioned distributed ledgers, control the information flow by granting network access only to a select group of vetted participants. Certain blockchains, such as Quorum, also offer so-called transaction privacy. With transaction privacy features, participants can specify that their information will be accessible to only a select set of participants. Transaction privacy thus permits more granular control of information sharing than private blockchain configurations.

SMART CONTRACTS ENABLE AUTOMATED, SELF-EXECUTING AND SELF-ENFORCING CONTRACTS

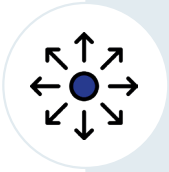
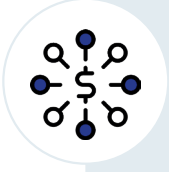
Blockchains can not only store information but also executable code, so called smart contracts. Once these small pieces of software are spread over the blockchain network, dedicated clients autonomously and automatically execute the code upon a certain trigger (if-then-logic). A smart contract could thus e.g. automatically settle a customer's bill once she check's out of a shared car. The smart contract could even prohibit her from using the car in the first place if she did not have a drivers license and the car wasn't autonomous. In this sense, smart contracts can control and automate contract execution between two parties - provided the code can reflect the actual contract's provisions.

BLOCKCHAIN CAN MEET IMPORTANT NEEDS OF A DISTRIBUTED OPEN MOBILITY SYSTEM

Blockchain technology can offer solutions to many challenges that a distributed open mobility system will face in the future. It can facilitate immediate and secure payment proccessing and tracking. Moreover, It allows secure and tamper-proof storage of information, while simultaneously guaranteeing that the information is distributed efficiently and thus available to the right recipients when and where needed. By and large, then, the blockchain can eliminate the need for any information intermediaries that capitalize on managing sensitive information. Smart contracts on the blockchain can furthermore improve transaction and payment efficiency by automating standardized business process logics.

Blockchain can also resolve current inefficiencies in cross-company identification of customers and mobility assets. It does so by securely storing a unique digital ID for each customer and all of their mobility assets. These digital IDs not only allow secure "single-sign-on" to any mobility services. They also allow seamless transaction and payment processing, while building customer preference profiles from stored information of past journeys. Ultimately, they can facilitate digital product memories for mobility assets, i.e., memories that store essential information over the asset's entire lifespan.

Table 4: Blockchain-based solutions to specific Seamless MaaS challenges

	Requirements of a decentralized Seamless MaaS system	Solutions implementable on a blockchain
	Effective payment mechanisms	Blockchains warrant immediate and secure payment processing and tracking
	Efficient and secure distribution of information	Blockchains represent highly secure and immutable distributed storage systems. As the global blockchain is continuously spread across the network, information is efficiently distributed. Additional privacy settings can ensure that only targeted recipients can access certain information
	Near real-time access to information	Local copies of the global blockchain permit near-immediate access to information recorded on the blockchain
	Disintermediation	Blockchains can eliminate costly intermediaries who would otherwise monopolize sensitive and valuable information
	Automation	Smart contracts facilitate standardization and automation of specific business logics, thus saving time and resources
	Secure identity & access management	Blockchains can securely store identities and can enable a global user account (“single sign on”) that governs mobility asset access
	Seamless mobility asset identification	Blockchains can represent physical assets by unique digital identifiers (tokens). These tokens make it possible to identify, reference, and transact with any mobility asset on the blockchain

BLOCKCHAIN REMAINS A NASCENT TECHNOLOGY

To date, blockchain is still a nascent technology, and we believe that its benefits will be best leveraged when its development is informed by and integrated with other highly scalable information storage and sharing technologies.

Information throughput

The amount of information that a decentralized blockchain network can process per second (information throughput) tends to be significantly lower than on traditional centralized networks. For example, the visa network can (by visa's own estimates) process up to 56,000 transactions per second, whereas the ethereum network can (theoretically) handle up to 20 transactions per second - projects are underway, however, to dramatically improve this limit [20,21].

Information latency

In many blockchain implementations, newly added blocks do not automatically become part of the global blockchain. Rather, many local instances can exist concurrently and therefore differ in the newest blocks. It is only after a certain time lapse that the blockchain network agrees on one of these instances as the new current global chain. Information not included in this version needs to be re-added, creating a certain latency period until it is brought in line with the global version, i.e. no sooner than the latter has been accepted by the majority of the nodes in the network. Continuous technical improvements, however, are bringing these latency periods below a single second [21].

Limited "on-chain" storage capacity

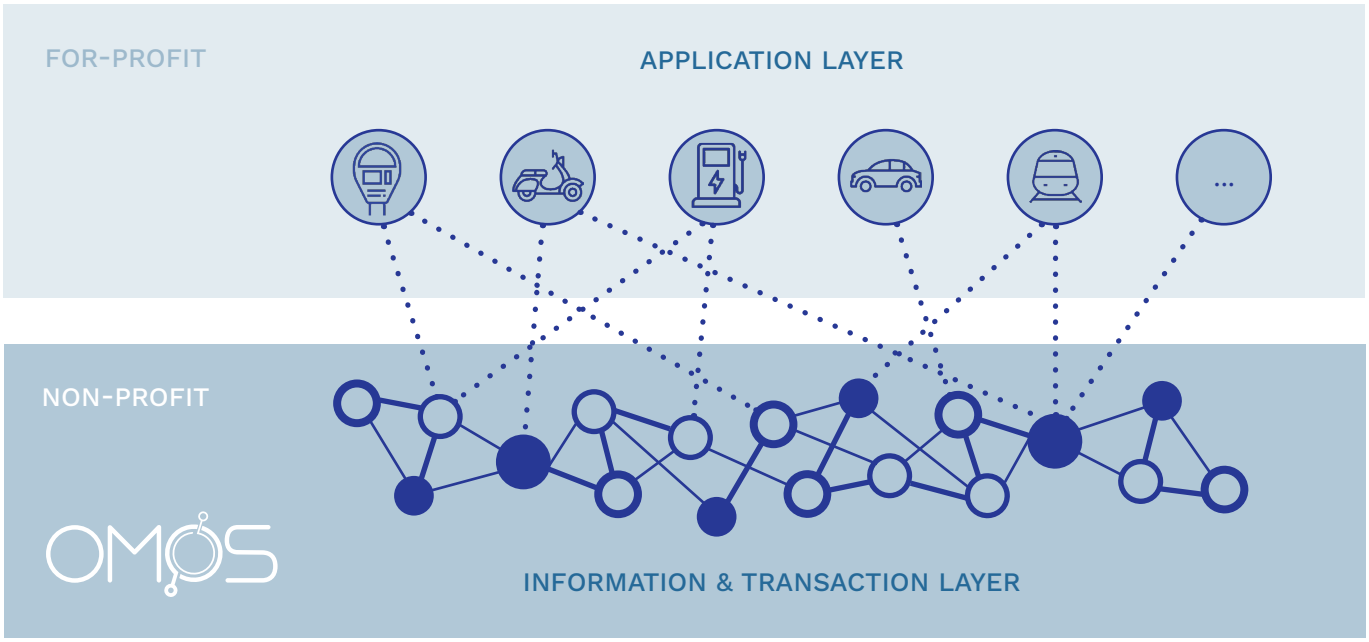
Blockchains are not designed for big-data storage, as each new piece of information requires additional storage capacity from all participants that keep a copy of the blockchain. New approaches are significantly increasing the amount of data, however, that can be represented on the Blockchain [22].

OMOS:
THE CONCEPT OF THE OPEN MOBILITY SYSTEM

OUR VISION OF OMOS

OMOS is more than a technological solution. OMOS offers an inclusive community ecosystem to jointly build the future of Seamless Mobility as a Service. By virtue of its distributed nature, OMOS empowers its participants to be equipotent and equally privileged so as to build the best solution for the digital infrastructure of the new Seamless MaaS ecosystem. While OMOS itself is a not-for-profit platform, it provides the infrastructure for all partners to design their own for-profit use cases. It is owned collectively by its participants and governed by the cryptoeconomic [27] internal governance logic embossed within the system's algorithmic consensus and transaction mechanism.

**Figure 7: The OMOS ecosystem -
an open and shared infrastructure serving for-profit applications**



PARTICIPANTS INVITED TO JOIN

Aiming to quickly build and foster a Minimum Viable Community [28], companies, institutions as well as private individuals are invited to join and shape OMOS. We welcome large-scale contributors from insurance and public transport companies, electricity providers, grid operators, car manufacturers and car sharing companies, as well as small-scale contributors from every citizen who wants to develop value adding applications. Based on our aforementioned analysis of the wider mobility ecosystem, we have identified four distinct roles that can be adopted within OMOS, though entities can have more than one role.

Asset Owners

This target group owns assets such as parking lots, electric charging poles, public transport assets, cars, scooters and bikes. By leveraging the Open Mobility System, asset owners can increase the usage rates of their mobility assets and thus generate additional revenue. What is more, advances in sophisticated data analytics make it possible to further refine offers and asset portfolios. Participants are free to choose the terms of engagement as well as the sharing of data. They may even choose their preferred mobility providers who will then gain exclusive access to their assets. Given the increasing autonomy of assets, ownership might well shift from current models to entirely new ones, ranging from crowdfunding projects to fragmented ownership of assets or indeed self-ownership of machines.

Mobility Providers

Mobility Providers offer their customers far-reaching mobility services. They can be public transport companies with inter-modal trip planner apps, insurance companies providing specific insurance products, current fuel card operators, or End-2-End mobility apps.
These companies will not only benefit from gaining access to more mobility assets. They will also be empowered to offer a new experience to their customers, since the decentralized platform logic of OMOS affords each company the ability to create and retain a distinct brand. Hence, unique customer experience will become the decisive factor in keeping customers, instead of today‘s “data lock-in“.

Application Developers

App developers are building new software products on OMOS, which can be leveraged by network participants. Given the open nature of OMOS, we have created an ecosystem in which individuals and companies around the world are invited to build new, highly customized applications. As a result, participants have a broad choice of software modules they can use for their end-customer products.

Institutional Participants

The fourth category of participants includes stakeholders from the wider mobility ecosystem, such as cities, financial institutions, insurance companies, auditors, tax authorities, legal firms, research institutes, and similar companies with a stake in the mobility industry. Cities and local authorities might choose to be connected to the urban infrastructure and mobility environment due to regulatory requirements imposed on the active players within their respective area of jurisdiction. This can play a significant role in the near future, when autonomous vehicles have a larger impact on urban life. In addition, financial institutions, insurance companies and auditors can leverage OMOS, for instance, to create and participate in new business models or service offers of MSPs. In short, the participation of the above-mentioned stakeholders will add a further degree of security and integrity by acting as validator nodes with the power to confirm transactions.

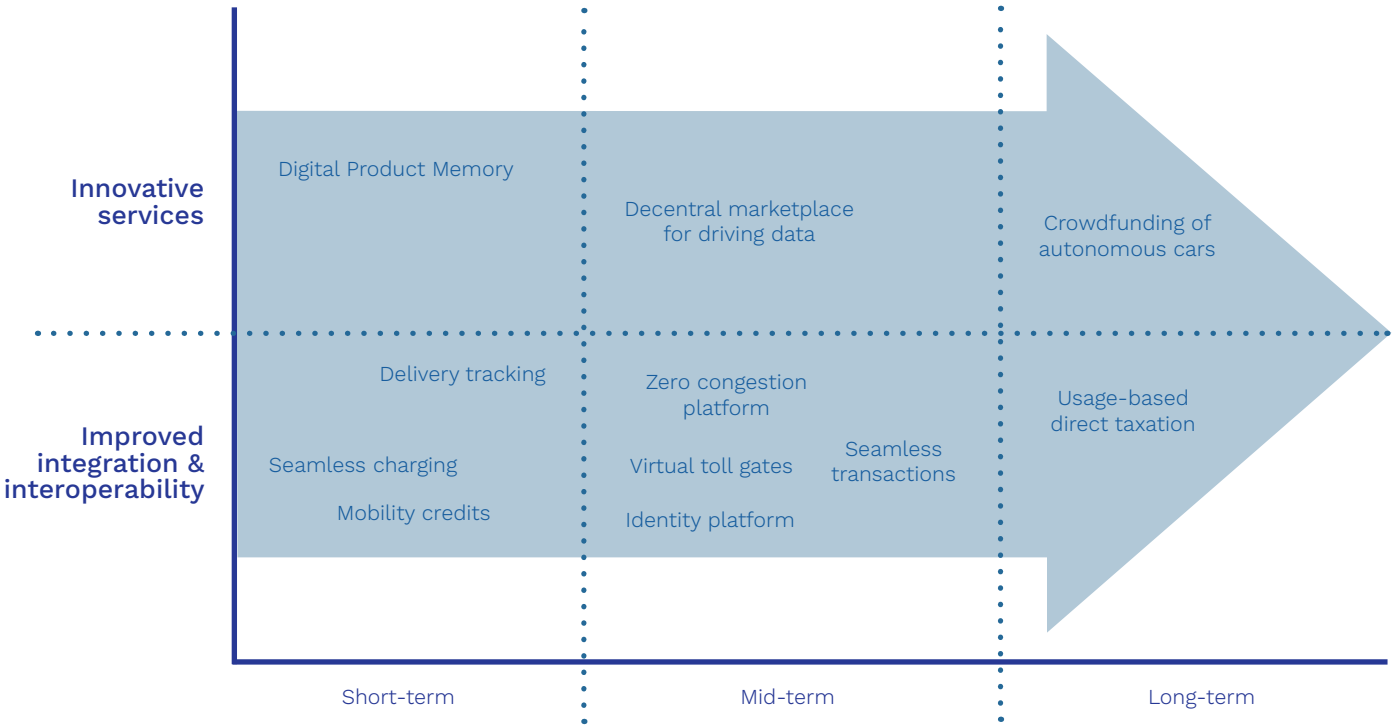
SEAMLESS MOBILITY:
INSTANCES OF CONCRETE USE CASES RELEVANT TODAY AND IN THE NEAR FUTURE

In order to collect, structure and assess use cases that may be relevant to Seamless MaaS and its wider ecosystem, we followed an open innovation approach and sought dialogue with industry experts, mainly from mobility service providers, the automotive industry, the energy sector, and blockchain developers. Based on interviews and workshops as well as our own in-depth analysis, we found that a large variety of use cases is suitable for OMOS.

Nonetheless, there would seem to be a common consensus that an accurate impact assessment of OMOS is impossible – at least at this point in time - both with regard to its technological and its organizational impact. Drawing a parallel to the early days of the internet, we find ourselves in a state of the unknown. Industry representatives consider decentralized technology a revolutionary step, yet, they remain unsure about its final outcome.

In the following, we present a selection of use cases divided into two categories: “Improved integration and interoperability” and “Innovative services”. Based on our experience from close engagement with the ecosystem as well as our own product development, we then estimate the “ecosystem readiness”. Influencing factors such as current product portfolios, emerging innovations in the “centralized” world, and the regulatory environment and cooperation culture are dealt with summarily in the assessment section. Thus, we hope to indicate an initial direction to understand the respective market relevance of each use case. Yet, as ever in such extensive fields, the presented use cases cannot pretend to cover the full range. It is our hope that this will be explored in future, collaborative work.

Figure 8: Use case categorization



Improved integration & interoperability

Seamless charging

Today: Private individuals as well as companies are registering their own charging poles, setting tariffs and defining which target groups are allowed to access them. P2P charge pole sharing was first introduced by Share&Charge, allowing electric car drivers to register and create a mobility wallet. Private consumers are hence able to charge with ease of access, pay directly, and even get paid in turn for renting out their own charge poles - the AirBnB of charging poles. Furthermore, the service is hassle-free for the charging pole operator, since transactions are cleared and settled in next to no time. They do not even require intermediary roaming platforms. In a next step, grid operators will directly interact with the charging pole and the battery of the car to enable smart charging and grid management. Overall system costs will be reduced dramatically, especially the cost of load balancing and that of charging electric cars.

Zero congestion platform

Imagine the following scenario: The data from all mobility assets is shared among its partners. Cities, with the help of AI specialized software companies, are evaluating the data and setting incentives to prefer or avoid certain streets at certain times. These incentives (or fines) are directly transferred to or from the wallet of the mobility asset.

Identity platform

Work in progress: Once registered, the user has generated a personal mobility wallet that is securely stored on OMOS and with which he can rent any vehicle registered on OMOS without prior notice. The Mobility Service Provider or Asset Owner retrieves necessary identity legitimating information such as the validity of the user's driving license. Only then will it grant access and generate revenue with a previously unregistered user. Accordingly, the identity platform can be used for any other use case based on personal identity legitimation, such as insurance contracting, private banking, and many more (see, for instance, Civic and uPort).

Mobility credits

Work in progress: Companies are increasingly demanding flexible and cost-effective solutions to employee mobility. As corporate fleets do not provide the necessary flexibility and cars have lost much of their value as status symbols, companies can offer their employees so-called "mobility credits", i.e. a mobility budget scheme, to pick and mix their desired modes of transportation. The blockchain's interoperability enables the usage of the tokens everywhere in the mobility system by use of Mobility Service Provider that can connect to the infrastructure.

Virtual toll gates

Imagine the following scenario: Toll bridges and roads are equipped with virtual toll gates at both ends. Once a car's location system indicates that it just passed through these virtual "geo fences", toll payments are triggered automatically and directly transferred to the wallet of the toll operator – thus reducing (operational) costs significantly and avoiding delays at physical toll gates.

Seamless transactions

Imagine the following scenario: Bob from Munich is planning to visit his mother in Amsterdam, so he purchases a door-2-door ticket via his preferred mobility app. He gets picked-up by an autonomous taxi, which brings him to the train station. Arriving in Amsterdam, Bob picks an e-scooter to cover the last two miles to his mother's house. Bob is able to rent the e-scooter without a driving license identification, due to the secure legitimation with Bob's personalized digital mobility wallet. In the meantime, the autonomous taxi has re-charged at the cheapest charging pole in the neighborhood. The overall bill is split between all the mobility service providers (taxi, train, e-scooter) and asset owners (charging pole operator). Payments are transferred instantly and directly to the according wallets.

Usage-based direct taxation

Imagine the following scenario: Depending on where and when you travel, you are taxed by city or state. Implemented instant taxation mechanisms allow for these taxes to be directly transferred to the wallet of the relevant authority, thus reducing complexity and cost significantly - especially in the case of cross-border transactions.

Innovative services

Digital Product Memory

Work in progress: Digital product memories allow us to represent physical, digital or biological objects in a secure digital repository. For instance, cars can be represented on a distributed ledger, in which their vehicle telematics data - e.g. mileage, trips, emissions and maintenance data - are recorded in the immutable repository. This auditable and tamper-proof mileage history can prevent odometer fraud in the second-hand market [23].

Decentral marketplace for driving data

Imagine the following scenario: All mobility asset owners (e.g. of cars) can share their driving data This comprises each car's own data as well as the sensor data from the car's surroundings. The technology allows extensive safeguards against misuse, unintended sharing is strictly prohibited, and it is in transparent accordance with the quality of data that companies define the price. This re-empowers users in governing their private data.

Prepared for the future

Delivery Tracking

Imagine the following scenario: Goods are tracked along their entire journey, with embedded handling of custom declarations, quality check registries and increased transparency among parties. Pilot projects of this system are already in operation [24], yet it remains to be seen how well they interact with a mobility infrastructure connected to the movement of people. Appropriate new business models and services would have to converge supply chain tracking data and data from personal mobility. This is where OMOS will prove useful, as it provides the required flexibility and openness to interact with other transaction infrastructures.

Crowdfunding of autonomous cars in a machine economy

Imagine the following scenario: Combining autonomous cars and blockchain technology yields the possibility of operating self-governing cars. This future scenario envisions a world of crowd-sourced mobility assets that are self-owning and indeed self-operating. Not only would they cover the costs of charging, tolls, parking and maintenance themselves [25]. They would even run at a profit.

"When eating an elephant take one bite at a time."

(Creighton Abrams)

Based on our previous experience, we believe that the development of the OMOS protocol will only be successful if it is informed by operating real products and services. Since distributed ledger technology is still very much in its infancy, the technological development of a new protocol for a seamless mobility transaction layer should be done in close collaboration within the mobility ecosystem. After all, it provides the right setting for collaborations to reveal technological, regulatory and customer experiences. OMOS' partners and regulatory bodies will benefit from a deep understanding of blockchain technology, its potential and its challenges. For a better understanding of the diversity of the current blockchain landscape as well as the elements which need to be considered in the development of a new OMOS core protocol, the following overview by Trent McConaghy is often useful [26].

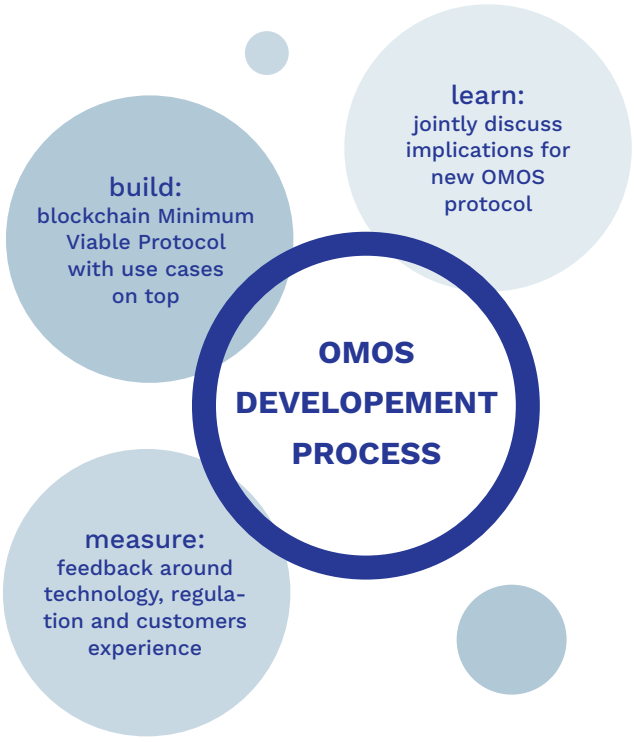


Table 5: The three elements of computing - decentralized [26].

Storage	Processing	Communications
Token Storage Bitcoin, Zcash, ...	**Stateful Biz Logic** Ethereum, Lisk, Rchain, Eos, Tezos, ... Client-side compute (JS, Swift)	**Data** TCP/IP, HTTP
File System IPFS/FileCoin, Eth Swarm, Storj, Sia, Tieron, LAFS	**Stateless Biz Logic** Crypto Conditions (e.g. BigchainDB) Bitshares and all stateful biz logic	**Value** Interledger, Cosmos
Database Bischain + IPDB, IOTA	**High Perf. Compute** TrueBit, Golem, IEx.ec, Nyriad, VMs, client-side compute	**State** PolkaDot, Aeternity

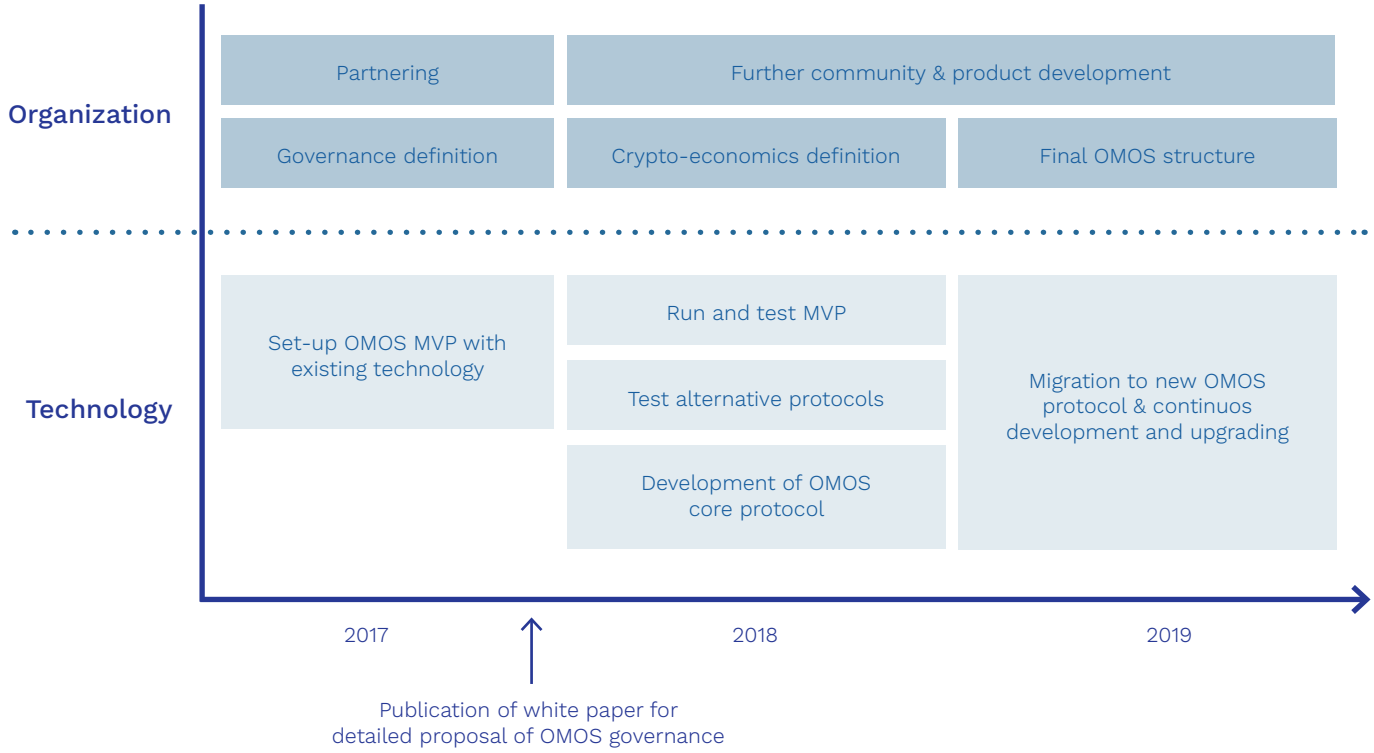
INFO

When we developed and started to publicly operate "Share&Charge", MotionWerk's first product, we gained a deep understanding of related issues such as regulations and auditing of the underlying technology. These insights would not have been possible with proof of concepts or prototypes.

In accordance with the principles of iterative development and a lean start-up approach, the OMOS minimum viable protocol (MVP) will be operative as of the beginning of 2018 with currently existing blockchain technology and onboarded real-life use cases. With this in place, other technologies need to be tested against use case-specific requirements to define a new OMOS core protocol layer which can host all relevant use cases while offering enough flexibility to interact with other systems.

The proposed timeline is structured in three organizational and technical phases from community building and governance definition in 2017 to the release of the new protocol, presumably in 2019. This timeline is intended to give an approximate idea of the potential next steps, one of them being the publication of a more detailed white paper around the exact governance of OMOS.

Figure 9: The development road map of OMOS



Phase 1

Building a Minimum Viable Community and defining OMOS‘ governance

Time frame: September 2017 to January 2018
Organisational process: Partners are invited to join OMOS, either to define the governance of OMOS (founding members) or to define further use cases to be applied and tested (strategic partners).
The governance structure will clearly define how individuals and companies can contribute and what they can expect from OMOS. It will also clarify decision making processes and the role of a potential legal entity. Thus, the funding structure of OMOS - potentially via a token generating event (TGE) - is formalized and ready to commence.
While the TGE would aid in the funding of OMOS and its community development, the next phase will focus on the exact crypto-economic [27] rules. Here, then, the token logic will be formulated in accordance with the learnings from the various use cases.
This first phase also comprises a more detailed mapping of further use cases, relevant partners, and the foundation of first working groups.
Technological process: Based on the learnings from the first year, and thus in accordance with the minimum viable protocol (MVP), the blockchain architecture will be further refined, tested and deployed with its founding members and strategic partners. A detailed overview of the current state of the ethereum-based blockchain MVP is provided in the technical appendix in the final section of this paper. After further technology testing, an additional protocol is kicked-off for in-depth assessment of the following three elements: storage, transaction processing, and communication.

Phase 2

Onboarding and core protocol definition

Time frame: January 2018 to mid-2019
Organisational process: Following the successful funding of OMOS, the partners are testing further use cases. Meanwhile, the OMOS core protocol is being developed. Subsequent to the potential TGE, the final crypto-economics for OMOS are determined. It is important to note that this process is essential to the project’s success, as the incentivization of the various stakeholders needs to modeled very carefully. The design of the digital economy, based on cryptography and economic theory, will require a thorough consideration of the underlying fiscal and monetary implications. At the same time, regulatory requirements such as data privacy, money laundering, or taxation must be considered accordingly.
Technological process: Companies, institutions and developers are invited to join OMOS on an application level as well as on the protocol level. An open and structured feedback process between the business and technology side will be critical in gathering the necessary feedback and translating the learnings into technical requirements of the maturing OMOS protocol.

Phase 3

“Go-Live” and continuous refinement

Time frame: As of mid-2019
Organisational process: The new operational protocol is released and partners are now using OMOS as the underlying transaction basis of their mobility products. Asset owners are connecting their mobility assets to OMOS and leveraging the interoperability with the ecosystem. New ecosystem representatives join by using OMOS to build for-profit use cases and innovative business models.
Technological process: Further development and adoption of innovations in distributed ledger technology.

INFO

One way of organising the development process and protocol governance could follow Outlier Ventures‘ framework for implementing tokenized digital economies (c.f. their recent white paper “Community Token Economies”). The framework proposes to incentivize collaborative behaviour with a shared theme (in our case Seamless MaaS) early in the development cycle to more quickly shape common infrastructure, build network effects, and generate economies of scale. [28]

Why we are starting now and inviting you to join

Our idea of the Open Mobility System is not merely about technological innovation, but also about triggering a revolution of organizational cooperation in the mobility sector. With OMOS, we wish to actively shape this future cooperation and engage with all interested partners around the globe. This paper, in conjunction with the ongoing MVP development, is intended as a first step for a global movement with strong partnerships among companies, research institutions and governmental bodies.

OMOS' benefits will be felt far beyond increased asset usage rates. Asset Owners such as charging pole operators, car owners, and operators of public transport infrastructure will enjoy the advantages of increased interconnectivity. OMOS will enhance asset accessibility for Mobility Service Providers wishing to implement innovative business models. Car sharing operators and public transport authorities, for instance, can thus generate higher usage rates and more frequent customer interactions, without becoming invisible to the customer due to a third party intermediary. OMOS will also open an unlimited window of opportunity for Application Developers, who will find many more ways to leverage the power of the decentralized mobility network. Public and private institutions, such as research institutes, insurance companies, and tax authorities, will similarly benefit from close integration with the emerging mobility ecosystem. Not only will OMOS permit to co-create the mobility system around their needs, they will also be able to streamline their service offerings for future customer needs.

In the course of discussing and developing OMOS with industry experts, however, we found that most (large) mobility incumbents hold out hope, or indeed believe with great conviction that they can establish a market dominating central platform. At the same time, very little is done to converge service and mobility asset portfolios in order to increase the overall goal of customer satisfaction. These thought and decision patterns adversely affect the development of Seamless MaaS and we believe that they are highly dangerous for mobility companies of the 21st century.

It requires a change in thinking and decision making.

The newly emerging mobility ecosystem is characterised by a sensitivity to environmental issues, cost and convenience-based consumer decisions, and a rising machine economy with entirely new ownership models. Joining OMOS in its first phase now offers the opportunity to actively shape an open and decentralized mobility system. We believe it will transform retrograde attitudes to private transport into fertile grounds for inclusive ideas and skills required in the future of seamless mobility.

More information about OMOS and the onboarding process will be available on our website soon. Stay connected and register for updates now on

WWW.OMOS.IO

We are looking forward to vivid discussions and an exciting journey.

TECHNICAL APPENDIX: THE INITIAL ARCHITECTURE OF OMOS - THE MINIMUM VIABLE PROTOCOL (MVP)

The first version of OMOS is based on ethereum, a public chain with the consensus mechanism of “Proof of Authority”. The main reason for our choice of ethereum is the availability of a strong developer community, its level of maturity compared to other blockchain technologies (we emphasize the relative character of the word “maturity” in the blockchain world) and its sophisticated Smart Contract capabilities. Moreover, our experience with our successful product Share&Charge, which leverages the public ethereum chain, helped us gain a deep understanding of both its potential and drawbacks. On the path to full decentralization of the system, trusted institutions are validating the transactions.

In phase two, we will test other protocols based on the requirements identified in collaboration with the partners. OMOS’ development will always strive to facilitate the highest level of interoperability with all leading distributed ledger technologies.

Current state of the Minimum Viable Protocol

The following table offers a general overview of the OMOS MVP’s key conceptual aspects, including its dual-token system, consensus mechanism, and transaction performance.

Table 6: OMOS - Table of features.

Open source	The client software is open source, with an open Application Programming Interface (API)
Open network	An open network, whereby any business or individual can install the client software and connect their node without requesting access to connect
Multi-currency Mobility Token	Platform services are purchased using Mobility Tokens that are backed by a fiat currency (e.g EUR, USD), depending on the preferred currency of the consumer and according to regulatory requirements
Transaction token	A native Transaction Token that will be used by nodes in order to pay transaction fees to validators
Ethereum compliant	Supports the publishing and execution of ethereum based smart contracts, written in Solidity with a web3 API layer
Proof of Authority (PoA)	The network consists of a subset of validator nodes that validate transactions and add blocks. The set of authority nodes is dynamic, so any new node can be added or an existing node removed at any time
Byzantine Fault Tolerant	The network can tolerate a certain level of faulty validator nodes by automatically correcting proposed transactions defined as invalid
Settlement finality	Has a near-instant settlement finality
Transaction throughput	Has an average transaction throughput of at least 2,000 tx/sec
Distributed file storage	Supports distributed storage of files (e.g. pdf documents) between network nodes
Efficient upgrading	Supports upgrades and software patches without disproportionate effort. The network will ensure fast and reliable upgrades of the client software

Roles of Network Nodes

A node in the OMOS MVP can be classified as either a *standard* node or a *validator* node. A validator node behaves as a standard node yet possesses extended capabilities in order to validate and create new blocks, as described in the following table:

Table 7: Node and Validator roles - Permissible actions of Nodes and Validators.

Action	Description	Node	Validator
Adds new transactions	Creates a transaction and broadcasts it to the network	Yes	No
Validates transactions	Receives broadcasted transactions and validates	No	Yes
Adds new blocks	Takes turns at creating new blocks and broadcasting these to the network	No	Yes
Receives blocks	Receives broadcasted blocks and adds these to their version of the blockchain	Yes	Yes
Propose new Validator	Can propose to add a new Validator to the validator set	No	Yes
Vote on new Validator	Votes on this proposed new Validator	No	Yes (configurable)

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About the Publisher

MotionWerk GmbH

MotionWerk develops blockchain-based software solutions for the mobility industry. With its first product „Share&Charge“, MotionWerk entered the market in Germany as of May 2017 and is currently in the pilot phase in several European countries and the USA.
Share&Charge allows the effortless sharing and billing of electric charging stations, equally for private persons and corporate partners. By pursuing the approach of close collaboration with major players in the wider mobility ecosystem, MotionWerk explores and develops decentralized technology for the future of mobility.

About the Scientific Contributor

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