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Leveraging the benefits of smart mobility via an integrated data platform

Prof. Dr. Felix Creutzig January 2020

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About the Program

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Against the backdrop of the Paris Agreement, the program invited policy professionals from Germany and Israel to explore issues relating to the transition to low-carbon economies with the aim of fostering increased cooperation and an exchange of ideas and knowledge between relevant stakeholders from academia, civil society and the government in both countries.

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Leveraging the benefits of smart mobility via an integrated data platform

Dr. Felix Creutzig

Increasingly abundant big data and artificial intelligence applications are restructuring economic activities and daily life. This is epitomized in the notion of the smart city, and especially visible on our streets, where e-scooters or pool-riding services are added every month and reshape our mobility. It's a time of experimentation and that may be a good thing. Yet, there are also signs of discontent, raising the question of how big data can be managed and organized in a way that reduces congestion and improves the daily travel routines of millions of citizens, supports the wider public good while also leveraging Israel's potential as a start-up nation. Here, we take the example of smart mobility in Israel to investigate how integrated data management can multiply the benefits of big data applications, while effectively managing risks. We find that integrated data platforms offer an opportunity to leverage benefits if three key design principles are followed:

1) open (but not necessarily free) data access;

2) maintaining the privacy, agency and participation of individuals, users, and the public; and

3) tailoring mobility services to meet well-defined goals of public policy.

Content

Introduction

There is no question that big data and artificial intelligence will shape our common future. Our smartphones provide and obtain an immense amount of data that help advertisers promote appropriate products and enable online maps to accurately predict optimal routing. Looking a decade ahead, ubiquitous facial recognition, drone delivery, and smart energy usage in buildings are likely to reshape our lifestyles if not our identity. Smart mobility plays a central role. As a keystone option, smart mobility emerges at the nexus of the global megatrends digitalization, urbanization, and climate change. Apps, big data and artificial intelligence enable the provision of the new mobility services that are enthusiastically embraced in cities worldwide, especially among young professionals, who appreciate the flexibility of multi-modal transport around the clock. Options include car sharing, e-scooters, bike sharing, ride pooling, and seamless boarding of public transit, topped off by the integration of multi-modal use in a smart mobility data platform that allows for frictionless use of a plethora of modal choices depending on the trip purpose, time and location. Smart mobility is self-accelerating: as applications require location data, services provide ever more of these data. But smart mobility is also constrained by existing infrastructure, path-dependent private vehicle use, and existing regulation.

As yet it is unclear what digitalization will bring. There are both enthusiasts and doomsayers, each convincingly arguing their case. The former predict a digital utopia where new technology will facilitate life and sustainable solutions; the latter see mass unemployment, surveillance states, and digitalization as rocket fuel for energy demand and climate change. There is no law that dictates what pathway will be taken. Instead, it is up to human agency to shape technology in our own interests. This requires active governance[1].

Smart mobility is heralded as a new solution for congested urban spaces. Yet a survey among Israel-based stakeholders reveals that smart mobility entrepreneurs are mostly concerned about commercial opportunities and lack a deeper understanding of what is required to transition to sustainable mobility[2]. Noy and Givoni state that "the belief amongst those entrepreneurs, it emerges, is that technological developments alone, specifically with respect to autonomous and connected vehicles, can lead to sustainable transport. This should be a real concern if those same actors are the ones who lead and pave the way forward for transport planning"[2]. Active government involvement is thus required to steer smart mobility for the public benefit.

This policy paper asks how big data and artificial intelligence methods in smart mobility can best be managed to deliver desirable goals such as incubation of further start-ups, less gridlock on streets, and better environmental quality. Given the hype about artificial intelligence and big data, and their potential to shape the technosphere and society, it is surprising how little attention is paid to the important role of governance. By directing technological innovation, vast potentials for improving the mobility of stressed urbanites and commuters can be leveraged – potentials that also have global market potential. It's time to move from 'smart mobility' to 'smart and sustainable mobility' and meet the unfulfilled demand for better urban and sub-urban living across the world.

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What are the key tools required to achieve these noble goals? There is wide agreement that data integration leverages potential for society and business. The hypothesis is that an integrated data platform (IDP) for smart mobility is central to the governance architecture of smart mobility. But the barriers to data integration, its societal risks, and the ownership of data and access rights are hugely contested. Some issues are intensively discussed among decision-makers, while other stakeholders quietly try to establish facts and aggregate a multitude of data. It's a good time to become active and steer the debate and the design of an envisaged data platform, enable participation by all relevant stakeholders, and give joint deliberation a place.

This policy paper proceeds in three steps. First, it will delineate the potential and opportunity of an integrated data platform. Second, it will discuss possible design options for the IDP. Third, it will suggest the next steps policy can take to advance the IDP.

The case for integrated data management

When it comes to smart mobility, there are multiple stakeholders, each with their own interests. Governments may want to improve the public good, at least in principle. Businesses seek new opportunities for innovation and profits. And citizens would like to improve their well-being and be active participants in decision-making and safeguarding their immediate environments. The relationship between these spheres is sketched out in Figure 1. Each perspective is discussed in turn.

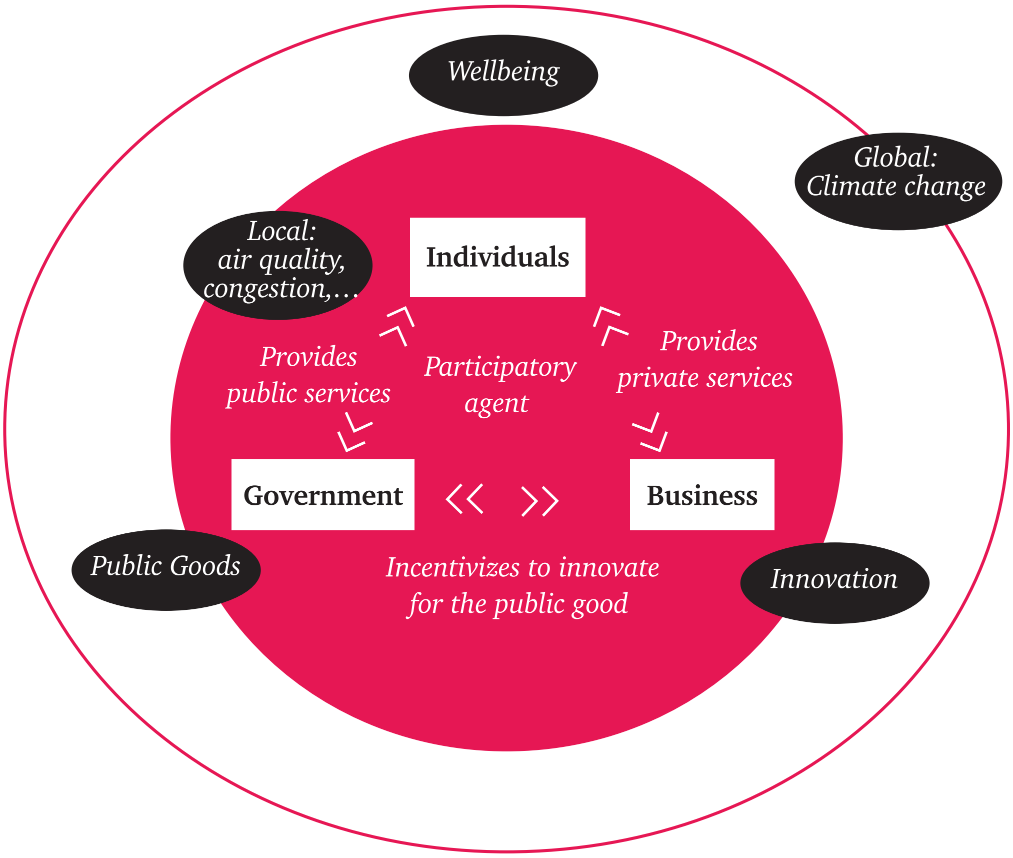

Figure 1. Agents with stakes in an integrated data platform on smart mobility.

Public Good Provision - Governments

On the one hand, governments are interested in providing an integrated data platform because it facilitates the effective provision of public goods and services, such as uncongested roads, urban planning for good quality of life, and improved air quality. On the other hand, governments may also want to invest in an open-access IDP to facilitate new business opportunities. In this function, an IDP would in itself constitute a public good by fulfilling two characteristics: every interested party can get access to the data; and every interested party can make use of data without compromising the ability of others to also make use of the data.

The supporting role an IDP can play in the provision of public goods is based on two arguments. First, that issues like congestion, air pollution, accidents and noise constitute major concerns that impinge on well-being and productive activities. Second, that an IDP can play a considerable role in addressing this issue.

Traffic congestion is a major burden on Israel's economy and quality of life. Although congestion has a negative impact on economies worldwide, Israel is disproportionally affected. While the numbers of vehicles per road space were broadly similar in Israel and small European countries in 1970, nowadays Israel has three times more vehicles per road space (Figure 2)[3]. Tel Aviv is in the top 5% of the world's most congested cities and ranks 19th in a worldwide congestion index, competing here only with large Asian megacities4. In peak hours, times in traffic can easily double from 30 minutes driving time to nearly one hour. Israelis spend an average of more than an hour in traffic each day. By the end of the next decade, it will be two hours a day. These costs of time translate into lost working time with an estimated value of about 2% of GDP[5]. Quality time with one's family is also eroded. Time in

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congestion is one of the main (cited) reasons for people being unhappy and stressed[6], facilitating street-network-wide aggression.

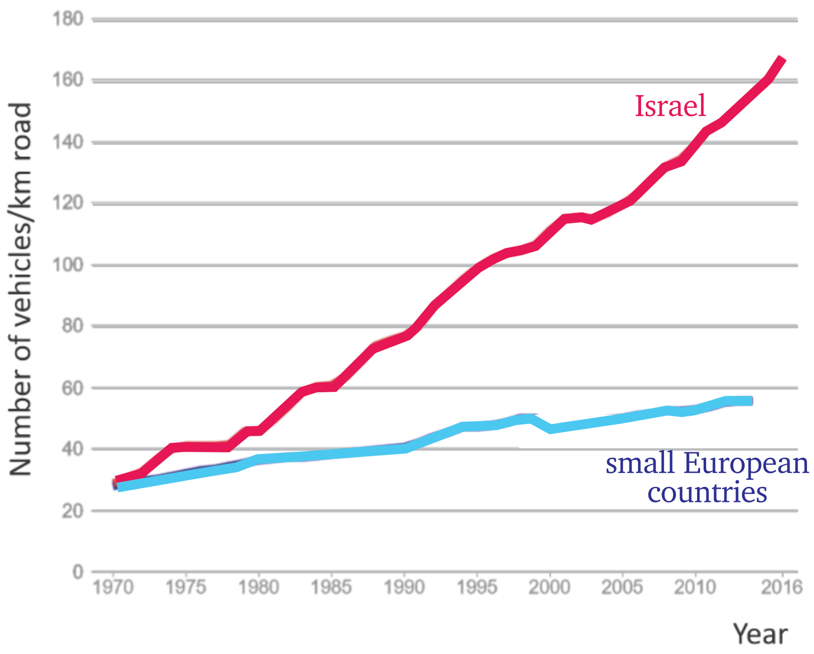

Figure 2.
Congestion on roads, measured as number of vehicles per road km. Comparison between Israel and small European countries (Belgium, Denmark, Netherlands, and Switzerland)[3].

Air pollution is another major problem connected to car traffic and congestion in dense urban agglomerations. In a 2012 report for the Ministry of Environmental Protection, Israel's external costs of air pollution from transport were estimated at about NIS 4.5 billion per year, or 0.7% of GDP. This is lower than estimated by a previous study conducted by the Finance Ministry's Scientific Department (2% of GDP)[7]. Yet both of these studies relied on extrapolating methods from the WHO and the EU. A case study of particulate matter 2.5 in Israel suggests that this pollutant alone – if attributed to vehicular sources – caused between 488 and 683 deaths annually. In terms of economic impact, this translates into external costs of between 0.84 and 2.3% of GDP[8], when scaled with the relative factors of the 2012 study on the external costs of air pollution with other pollutants included. Air pollution is closely associated with asthma, cardiovascular diseases and lung cancer. Six per cent of Israeli male soldiers suffer from asthma[9]. Reducing air pollution reduces the burden on hospitals, and facilitates better economic and social participation.

Accidents, noise, and climate change are other notable costs of car transport. Accidents are one of the deadliest dangers of daily life, especially to pedestrians. According to OECD data, the share of pedestrian fatalities in total road fatalities is higher in Israel than in most industrialized countries, accounting for nearly one third of all road fatalities[10]. In 2017, there were 323 fatal road accidents. With the costs of each life estimated at around 2.4 million EUR (taking EU standard values adjusted for GDP PPP in 2017), this translates into about 0.25% of Israel's GDP, ignoring the social costs of injuries and vehicle damage.

While climate change costs are high, their effect is globally distributed, a key difference to the other externalities that are of direct local concern. Israel's land transport was responsible for 17.7 MtCO2e in 2015, which translates into a shadow price of about half a billion $US, or 0.17% of GDP in 2015, assuming current EU ETS price levels of about 28€/tCO2. The real social costs of carbon are more difficult to ascertain, but are likely to be higher by at least a factor of 10[11], amounting to about 1.7% of GDP. Given that leading climate economists agree that the likelihood of social system collapse due to extreme heat and storms, insufficient foods supply and malnourishment, and resulting conflicts is constantly increasing[12], there is a strong case for pursuing radical climate change mitigation, too.

Altogether, the externalities of car transport in Israel amount to between 3.2 and 6.3% of GDP (Table 1; noise and injuries are excluded from this calculation). Research on the relatively extreme case of Beijing has shown that externalities of car transport due to congestion, car accidents, climate change, and, to a lesser degree, air pollution can cost between 7 and 15% of GDP[13]. As a result,society is spending huge amounts of money on defensive costs, most of which could be avoided and redirected into productive investments that improve well-being and pave the way to a future-proof economy.

Table 1. Social costs of road transport in Israel (data between 2012 and 2018).

Social cost dimension	Social costs in % of GDP	Source
Congestion	approx. 2%	OECD, 2019
Air pollution	0.8-2.3%	Ginsberg et al, 2016
Accidents	0.25%	National Road Safety Authority
Climate change	0.17-1.7%	Mattauch et al, 2019
Total	**3.2-6.3%**	

The key question is then how an IDP can support the transformation of the transport system in order to improve the daily life of commuters and residents in a notable way. A short look at urban areas that boast a high quality of life, as evidenced by multiple rankings, such as Vienna, Zurich or Copenhagen, reveals that an IDP is not necessary to bring about the envisaged benefits. These cities are built on a dense and high-capacity public transit system, urban planning as transit-oriented development, and bicycle highways, with restricted parking in inner cities. The Tel-Aviv lightrail will improve the situation, but it will not suffice to have notable impact in a growing economy. The real question is thus whether an IDP can support the reduction of congestion, air pollution, and accidents when high investments in public transit are politically not feasible, or when suburbanization makes efficient public transit difficult to realize. And here the answer is a resounding yes.

The key to envisaging a congestion-free, environmentally friendly urban transit system with limited public transit capacity (although some capacity must be there) is shared mobility. Radical shared mobility scenarios demonstrate that congestion-free travel is possible even with cars. The International Transport Forum conducted two key studies that modeled shared mobility scenarios for Lisbon and Helsinki. The detailed models show that replacing private car traffic with new shared mobility services in urban areas dramatically reduces the number of cars needed, cuts CO2 emissions, and frees large swathes of public land for uses other than parking—without making it more difficult for users to get from door to door. With these shared services, all of today's car journeys in Helsinki's Metropolitan Area could be provided by just 4% of the current number of private vehicles. The best results in terms of reducing emissions and congestion are achieved when all private car trips are replaced by shared rides:

- CO2 emissions from cars would fall by 34%;
- Congestion would be reduced by 37%;
- A lot of public parking space could be used for other purposes.

Shared mobility also means fewer transfers, less waiting, and shorter travel times compared to traditional public transport. This could attract car users that do not currently use public transport and encourage a shift away from individual car travel.

A key requirement for achieving frictionless radical sharing scenarios is the seamless integration of different transport modes with an IDP. One

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advantage of this scenario is that it does not require massive infrastructure investments and may be faster to implement and generate tangible results compared to expanding the railway infrastructure. It may also be preferable because of the higher system speed (travel time from door to door) it facilitates. It will, however, still depend on mass rapid transit along key arteries and corridors that would otherwise still be congested if used only by shared mobility. Finally, such a smart shared mobility scenario may be particulary fitting for Israel as a tech-affine start-up nation.

Innovation – Business

The second key argument to be made for fostering an IDP in Israel: Access to integrated mobility data and the provision of a vast opportunity space for shared mobility can fuel the Israel start-up economy. Values generated in mobility are rapidly shifting from hardware (cars) to software (digitized mobility services). Business and start-ups have significant interests in integrated data. Machine learning algorithms require considerable data of high quality to be trained and used for generalized learning and new applications. Companies that leverage customer behavioral insights outperform their peers by 25% in gross margin[14]. Israel is in an ideal position to reap future rewards, and an IDP could serve as the capital and infrastructure that allow start-ups and business to thrive. The argument is that (mobility) data is required to train and implement any sort of algorithmic mobility service, and to provide ample innovation space to try out new solutions. For example, e-scooter providers can optimize the location where devices are deployed. And urban planners can optimally plan high-quality bike and two-wheeler networks.

The business sector has perhaps the most direct interest in an integrated data platform. A plethora of imagined and unforeseen business models

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and innovations could be established with the help of big data and machine learning tools. The most obvious case is the provision of multi-modal integrated trips that are flexibly designed according to time, space, and needs. With app-integrated routing and ticketing, the transaction costs of travel can be drastically reduced. Access to integrated data platforms can serve as an innovation booster and generate profits, possibly distributed across many parties.

Within the automotive industry in Israel, new start-ups in smart mobility spring up faster (13% annually) than those in autonomous mobility (10%) or electric mobility (7%)[15]. However, the smart mobility start-ups are more likely to rely on seed funding and have so far been less likely to make it to the revenue growth stage[15]. Access to an IDP may offer the potential to scale existing business ideas. Smart mobility start-ups would profit from an integrated data platform in the conventional sense of being able to make profits, and in the wider sense of making use of a powerful resource to explore new solutions, thus enabling innovation. The widest sharing of benefits, for both customers and companies, is achieved when returns are obtained as profits, not as data rents.

Participation and Public Spaces - Consumers and Citizens

Individuals have a two-fold interest in an integrated data platform for smart mobility. First, they would stand to benefit from most of the mobility services that make use of the integrated data platform. Seamless integrated transport facilitates the daily commute and, perhaps more importantly, trip chaining, possibly also addressing gender discrimination in today's transport system. Second, citizens may themselves make use of the integrated data platform, for example by

computing relevant metrics at neighborhood scale and subsequently visualizing this information to lobby for modifications in street design or transport infrastructures. Well-designed access to high-quality data can (re-)empower individuals, turning them from pure consumers into active societal agents – citizens.
In the words of Malka Older[16]:

"[…] democracy was never supposed to be a perfect clockwork mechanism, functioning on its own while citizens went about their lives, mitigating with preternatural precision every failure of human nature. Democracy is about people actively engaging with the decisions of their government at every level. It requires creating the space and processes for that to happen, providing education to enable an informed citizenry and putting in place safeguards to prevent oppression by the majority — and then continuously improving and adjusting those components as society changes. In our technology-rich world, with a surplus of wealth and leisure time, we should have more opportunities to facilitate and extend democracy than ever before."

Our mobility patterns concern our daily life, and active engagement by citizens with data will only help governments to find fitting solutions. In turn, with the appropriate specifications, an IDP can serve to establish community data ownership, thus bringing economic rights to primary data providers and citizen groups, which in turn can support democratic functioning[17].

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Figure 3. summarizes the benefits of an IDP for different stakeholders, and their interaction:

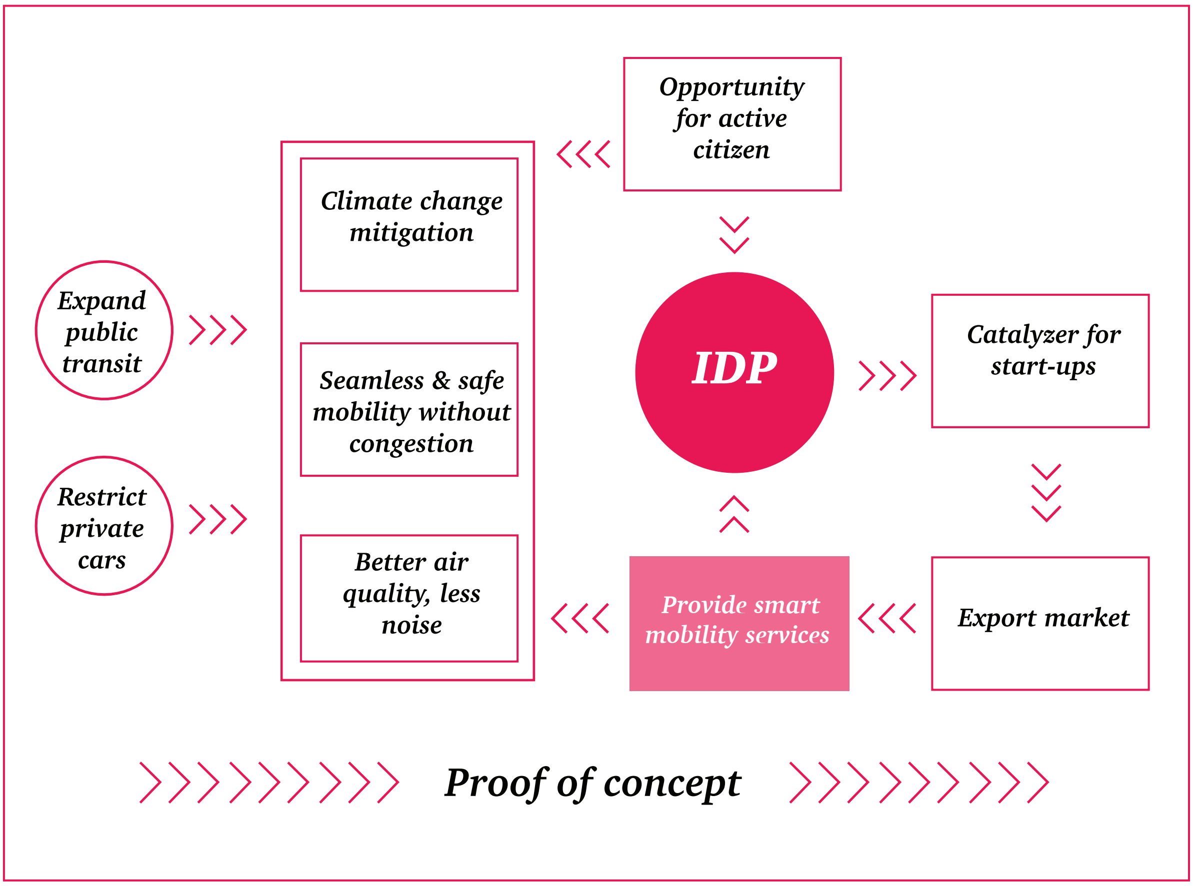

Figure 3. Benefits of an IDP.
The central product of the IDP is the provision of smart and sustainable mobility services. Public benefits, such as seamless and uncongested mobility, are achieved through coordination with other policies, such as the expansion of public transit and the phasing out of private vehicles in inner cities. Start-ups would benefit from data access to provide better smart mobility solutions, which in turn increases the public benefits. Moreover, evidence that smart and sustainability mobility solutions work can help business to export those solutions worldwide. Citizens themselves may also get involved and help to design locally appropriate solutions by making use of the IDP and actively engaging with mobility governance.

Characterizing an integrated data platform [IDP]

The IDP will be defined within two main design categories: 1) Data quality and quantity; and 2) Ownership and access rights; and by one key outcome category: 3) value generation. Box 1 provides relevant definitions. Let us discuss each in turn, starting with the value generated, since the identification of a desirable outcome will also help to define the architecture of the IDP itself.

Box 1. Definitions

Integrated data platform (IDP): a framework and/or institutions where smart mobility data are integrated in order to serve various constituencies (public good, business, consumers, citizens) simultaneously.

Data controller: the person or entity that exercises control over data and defines the purpose for and the manner in which data is processed.

Data environment: The data environment is defined by four characteristics[18]: 1) the agents who have access to the data; 2) any other data to which the data can easily be linked (involving the degree of potential re-identification); 3) the governance of the data; and 4) the infrastructure used to store it, including hardware, representation languages and cybersecurity measures. Data may be held in a range of data environments – which together constitute a 'data situation'. Data controllers need to be able to map and understand data environments and the data situation.

Data trust: proven and trusted frameworks and agreements that will ensure exchanges of data are secure and mutually beneficial. A data trust may include an integrated data platform (IPD). An IDP may or may not be part of a data trust.

Measuring success

Outcomes and value generated will depend on the use value for various constituencies and purposes, as outlined above for business, consumers and citizens, and governments and administration. Specific metrics are summarized in Table 2. Specific ex-post evaluation metrics could consider the additional value generated by applications building on the IDP data, and possibly even the number of start-ups emerging as a result of having access to an IDP. Second-order success metrics could register the export of products, since there is considerable demand for shared mobility applications worldwide.

Evaluation metrics for governments would center on macro-economic metrics, such as improved GDP and defensive health expenditure due to improved mobility and better air quality, as well as softer metrics, such as satisfaction with administrations and restored reputation and trust in public institutions.

Evaluation metrics for customers could take account of effective time saved in traffic and subjective improvements in happiness. Examples of successful participation through utilizing an IDP could be evaluated by monitoring citizen empowerment and trust in the government.

Table 2. Success metrics for the design of an integrated data platform.

	Metrics	Example
Innovation	• Number of start-ups • Export value generated • Counterfactual increase in profit margins	Organizations that apply machine learning on integrated customer data outperform peers by 85% in sales growth and by more than 25% in gross margin[14].
Public goods	• GDP improved due to better mobility and air quality • Planetary health	The most ambitious shared mobility scenarios predict a reduction of congestion by 37%, of CO2 emissions by 34%, and the opening up of open spaces formerly used for parking[19].
Consumer benefit	• Time saved in traffic • Reported subjective well-being	Shared motorcycles in Djakarta provide a substantially improved commuter experience[20].
Operational benefits	• Revenues or fees obtained from providing data access and services • Voluntary donations	Wikipedia provides high value for users, which is partially compensated by voluntary donations.

Measuring costs and risks

Costs and risks include both the direct investments in an IDP as well the misuse of an IDP and undesirable second-order effects.

Direct costs include spending on personnel, server capacity and infrastructure, and other running costs, such as rents. A full business plan would need to be developed. Initial calculations for a 200m2 office in a central location, five highly qualified data scientists, three contractual lawyers, and three management positions, as well as administrative support staff, plus server capacity and other infrastructure costs amount to about NIS 12 million annually.

Risks include the misuse of data, such as travel-route profiling of individuals and the commodification of data without consent; the development of an undesirable data monopoly and resulting antitrust concerns; and the abuse of integrated data for political purposes, especially, but not only, by authoritarian regimes. For example, if people feel and are constantly tracked in their movements, governments and business can easily socially control entire populations[21]. The metric to maintain here is data privacy, i.e. the fundamental right of personal protection as related to data use. This is, however, not only about individual rights, but also about the potential for mass manipulation by algorithmic structures. Hence, the protection of autonomy may be the more encompassing notion to be aspired to.

With the advancement in the location tracking capabilities of mobile devices, data privacy and autonomy concerns are becoming more pressing. Location data is some of the most sensitive data being collected. A list of potentially sensitive professional and personal information includes the identity of the user, their home address, individual interests as well as significant events, such as participation in demonstrations or a visit to an abortion clinic or church. In fact, just four spatio-temporal points, approximate places and times, are enough to uniquely identify 95% of 1.5 million people in a mobility database – even when the resolution of the dataset is low[22]. Therefore, even coarse or blurred datasets provide little anonymity.

With the advancement in the location tracking capabilities of mobile devices, data privacy and autonomy concerns are becoming more pressing. Location data is some of the most sensitive data being collected.

One operational risk is that integrated data will be of questionable quality and not sought after by any constituency.

The above analysis of costs and benefits points in two different directions, highlighting on the one hand the need a) to provide high-quality data in large quantities that can be used by everyone; and on the other b) to restrict and prohibit the use of personal data. However, even the risks can be turned into opportunities if data management translates into ownership consistent with broad participation and democratic engagement[17], greater trust, and transparent and smooth access to relevant data, where agreed upon, for government agencies and business. We will see below how this apparently hard trade-off may be solved, at least partially, by design principles and technological solutions.

Data quality and quantity

In each case, proper access to large quantities of high-quality data is desirable. For innovation, a lot of high-quality data is desirable, where possible from various domains to open up a space for innovations whose potential may not yet have been identified. For example, a detailed online monitoring of general travel data, together with e-scooter-specific data, may enable e-scooter and other shared mobility data to optimally relocate vehicles, while also taking transaction costs into account.

Data for shared mobility include on the one hand data on infrastructures and transport networks, such as street maps, maps of street allocation for different modes, public transit stations and networks, settlement structure and population density, street connectivity, and the socio-economic characteristics of neighborhoods. On the other hand, they also include individual travel data, such as origin-destination matrices, individualized trip-chaining data, travel diaries, and use behavior of transport modes. They may even code implicitly or explicitly for purpose of travel. This is important for understanding the service quality underlying mobility and for developing new solutions.

The first kind of data – infrastructures – is mostly risk-free, insofar as personalized data are not involved. Exceptions are security considerations and the identification of vulnerable infrastructures. The second kind of data – personalized data – is subject to data protection laws and entails substantial risk of abuse, as well as the potential of self-enslavement to data technology. It is therefore crucial to maintain data privacy and autonomy.

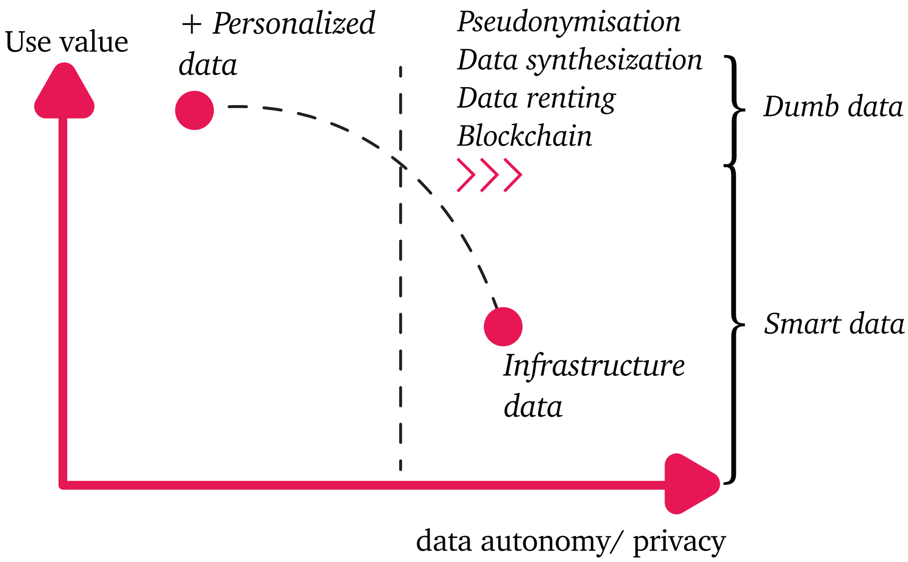

Figure 3.
Trade-off between the use value of data and user data sovereignty. Infrastructure data have use value without compromising user sovereignty. Personalized data add considerably to use value but can severely compromise data sovereignty. A focus on the most valuable personalized data can achieve most of the use value while maintaining most of the user data sovereignty.

The apparent trade-off between the use value of data and the maintenance of data autonomy is shown in Figure 3. The figure also indicates how the trade-off can be dealt with effectively. First, infrastructure data usually maintain data autonomy and can already generate some use value. Second, not all personalized data has the same value. A focus on the most valuable data only may realize most of the use, while minimizing the loss of data privacy and data autonomy. Given that less may be more, it would make sense to collect only the most valuable personalized data in the first place. Additional data could be designated as ‘dumb data’ and ignored (Figure 3). This has the added benefit of reserving valuable server space and man-hours spent on data cleaning for the most valuable data, thus saving money and personnel resources.

Data controllers can also draw on technological options to minimize the trade-off. First, data can be de-identified, for example by separating location data from a person’s name and other unique person data. This could be taken as a first step, similar to the procedures adopted by TIMNA, the data science office of the ministry of health, to protect highly sensitive integrated health data. This is only a soft safeguard, however, as sophisticated programmers can often re-identify people.

Second, data statistics can be randomized and synthesized into new datasets with identical statistical information but synthetic identities. Such services are already delivered by a private company, MDClone, which offers a new healthcare data paradigm, enabling fast and direct access to healthcare data while fully protecting patients’ privacy. Using original datasets, MDClone’s Synthetic Data Engine creates anonymous data statistically identical to the original but with no actual patient information.

A third security mechanism is access via remote lock-in, not including data transfer. In this case, hybridizing with other data sources, which could help to re-identify personae, is blocked or requires an additional permission process.

All of these technological options expand the boundaries of the trade-off towards the most desirable outcomes of high use value and minimal data privacy inference (Figure 3).
Altogether, a key design feature of an IDP is its level and quality of data preparation and protection.

Services provided

An IDP also needs to be defined in terms of the services it can or should provide, for example with regard to:

- the level of access granted at different levels;
- whether it stores data or serves as intermediator between data controller and beneficiary;
- any role in acquiring data;
- the amount of data preparation and cleaning;
- the provision of ancillary services, such as standard AI tools for interested parties without own capacity.

Desireable Properties

Altogether, an integrated data platform may have the following desirable properties (following[18]):

A. Transparent interface. Users need to be able to ascertain the existence, properties, and quality of the data in the first place.

B. Provenance. Potential users need to be able to assess the quality of data by getting access to metadata about its provenance and other properties.

C. Access controls. Data controllers – managers of the IDP or third-party data controllers relying on the IDP as an interface – need to be able to retain control over who gets access. This can follow transparent rules, or individual negotiations, especially in a more decentralized data trust format. The liability for data protection breaches remains with the IDP or individual data controllers.

D. Access. There must be mechanisms and tools for obtaining access to data. Access may be partial, and limited to synthetic data, or limited to data-renting formats. Access may also be conditional on, for example, contributing to the overarching goals of the IDP.

E. Identity management. The identity of those gaining access to data is tracked.

F. Audit. A record of uses of data needs is stored subject to audit for compliance with legal requirements, ethical principles, and the mission of the IDP.

G. Accountability. Data controllers and data users must both be held accountable in the case of data misuse.

H. Impact analysis and learning. Use and value generated, but also misuse, must be recorded and evaluated to constantly improve the design of the IDP through iterative learning.

Ownership and Access Rights

Ownership and access questions constitute the fundamental governance domain of an IDP. Here it is important to recognize that ownership is a-priori an indeterminate term that does not specify the options that an owner has with respect to land/property. Different specifications are possible. Honoré[23] identifies eleven possible characteristics of ownership:

1. The right to possess (exclusive physical control)
2. The right to use and access
3. The right to manage
4. The right to the income
5. The right to the capital (power to alienate or destroy)
6. The right to security (immunity from expropriation)
7. The incidence of transmissibility (heritage)
8. The incidence of absence of term (no expiration)

9. The duty to prevent harm
10. Liability to execution (forfeit interest in case of insolvency)
11. Residuary character (right to reversion of rights)

This insight opens up a space for highly differentiated considerations of ownership. For example, one party may possess and manage the data while other parties have limited or unlimited access rights. If the first party is also obliged to prevent harm but is excluded from the right to the income, an effective separation of regulatory power and commercial interests is ensured.

Key design questions then revolve around who owns the data, who regulates it, and who has access and usage rights and to what degree. Technologies, such as a data renting, make it possible to expand the scope of different options.

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Another question touches on the sourcing of data. Who brings the data in? Public institutions? Or private institutions as well? And what about data donations by interested citizens? And why should third parties share their data with an IDP in the first place?

Essentially, there are two data-sourcing paradigms. The first could be labeled: barter and negotiate. In this paradigm, the IDP negotiates with third parties on conditions and possibilities of data exchange and acquisition. The second could be labeled: regulate and govern. In this paradigm, an IDP is simultaneously an effective regulator and provides, for example, licenses for shared mobility conditional on data sharing and, possibly, sharing services that improve the larger public good in some to-be-defined sense.

Let's now break these considerations down into specific governance options and design solutions.

Governance Options and Design Solutions

Governance options include market-based solutions (laissez-faire; monopoly), private-public interface (regulated market), an aggregating governance agency, and solutions in a third domain (data trust; decentralized data) (Table 3). All of them could be realized but they differ in key ways.

Laissez-faire and monopoly are two private sector-oriented data governance options. These are very important benchmark options as one of them will arise by default if there is no dedicated initiative to bring data governance into the public space or organize it as a commons. There are clear advantages to these options. They bring the private-sector expertise in delivering solutions for consumers to the forefront. However It is not unlikely that laissez-faire will transform into the monopoly or an oligopoly option, as working with hybrid big data and machine learning requires substantial capital investment beyond the capacity of smaller companies, at least when delivered as a whole portfolio of solutions. The laissez-faire option has the added advantage of enabling further experimentation by start-ups and bigger companies alike. Both options are, however, deeply problematic. Private companies have few incentives to deliver solutions that benefit the public good, even when they claim to have green, smart, or sustainable credentials. Equally problematic is the fact that both options will keep data in a proprietary format, stymying the generation of new business opportunities and sustainability solutions by new market entrants or interested parties. In this case, companies will aggregate data, sell some of the data at their discretion, and gather high data rents, which in turn stifles innovation by other actors. In some cases, data will be withheld, and even government agencies won't be able to buy data that would be useful for designing public policies (for example, Google withholds data from the Ministry of Transport that would be useful for reducing congestion). Proprietary data will serve their holders, not the public.

A second array of options entails a higher degree of involvement by the government. This can happen via a regulated market or a central government agency that aggregates the data. In the 'regulation' option, the government could mandate data-sharing arrangements and also prohibit the formation of a data rent-seeking monopoly. A disadvantage is that the regulator is often years behind in terms of technological development and may be challenged to dynamically design the best regulation for rapidly changing contexts.

A central government agency can aggregate all relevant data and utilize it, in principle, for the public good. As part of a large bureaucracy it may, however, be less well positioned to develop solutions that serve the users of smart mobility. Depending on the specific institutional setting, it is also not clear whether the organizational mindset is appropriate to delivering solutions such as easy access to the IDP for start-ups or measures to reduce congestion and improve mobility. Another key concern is data security and the potential for abuse by an authoritarian surveillance apparatus.

A data trust or foundation could help to ensure that an IDP serves the wider public good and is used appropriately. Data trusts are "proven and trusted frameworks and agreements" that will "ensure exchanges [of data] are secure and mutually beneficial" by promoting trust in the use of data[24]. They are supposed to "provide ethical, architectural and governance support for trustworthy data processing"[18]. Data trusts are motivated by the understanding that data protection laws are formalistically narrow and insufficient to build trust between agents and institutions working with or being the subject of data. Data trusts are frameworks that are intended to overcome the lack of trust, but do not require any new legal action. So far, a data trust has not been considered for the case of smart mobility, even though it could deliver multiple benefits.

As its central feature, the data trust would operate as an independent not-for-profit entity – neither public nor private – with a clear mission. The mission would be decided by a governing board of relevant stakeholders and could include serving the specific goals of combatting congestion, planning for low-carbon and highly accessible urban infrastructures, and providing data access for start-ups. It could also provide technical (machine learning) expertise for public entities, such as municipal governments, that seek to make use of the data to enhance the provision of public goods. The data trust's mission could also be to specify limits to data aggregation and a stringent securitization of the data, e.g. by de-identifying data or resampling data to synthetic formats, and by data-renting formats. Ideally, it would be run like a private business but with the goals of a public agency. A data trust could also contribute to co-design with citizens and data-sharing formats, e.g. by enabling citizens from specific districts to help design their district based on existing data, and, possibly, by integrating new data provided by citizens.

A data trust does not have to be an IDP (see Box 1). For example, a data trust could be an institution that manages metadata (who controls what quality of data, including its provenance) and data-sharing tools, thus acting as an intermediator between data controllers and beneficiaries.
A last design solution is decentralized and based on blockchain technologies. Blockchains may be the best solution in cases where either the capacity for or trust in an integrated data platform is lacking, possibly in large parts of the world[25]. Via smart contracts, blockchains

would guarantee trusted and safe interaction and payments for smart mobility. Via distributed ledgers - i.e. communication protocols that enable administratively decentralized, replicated databases - cryptographic security, auditability, and automation of business processes can all be guaranteed. A global blockchain infrastructure for shared mobility could be built on Linux open-source Hyperledger project[25]. Because of the resulting very low transaction costs and high degree of trust, a blockchain-based approach to shared mobility could unleash a wide variety of new business opportunities and solutions.

A key question is whether decentralized blockchain technologies can also deliver public goods and other IDP goals. In a direct way, the answer is negative, since data-based solutions based on data integration are not possible. However, there are two ways in which blockchains could still be compatible with the goals of reducing congestion and improving air quality. First, individual users could voluntarily share their personal data for specific purposes, also via blockchain technologies (data donations), or sell the data individually and in various formats to private enterprises. Second, distributed ledgers might also contain information on time, location, situation, and vehicle, thus coding for congestion, fuel quality, CO2 emissions, and other issues of public interest. Payment transactions could consider these properties, and protocols could be designed to ensure that economic incentives align with the provision of public goods. This solution would require considerable development in blockchain technologies as well as considerable public policy in order to integrate all mobility users into the decentralized system.

Table 3. Six governance options for an integrated data platform for smart mobility data.

	Laissez-faire	Monopoly	Regulated	market	Data trust/ Foundation	Decentralized data
Description	Business and actors are left to themselves to explore options. Everything goes that does not explicitly contradict existing laws.	A monopolist sucks up all relevant data and uses them for rent generation.	Smart mobility data is left to business but their use and exchange is regulated.	An independent foundation is established that has a mandate to govern big data on smart mobility for the public good	A government agency manages and controls critical smart mobility data	Data are transferred decentrally with blockchain technologies; regulating agency maintains standards and open access
Benefits	Wide open space for experiments; unforeseen cool stuff could come up	Data are integrated and can fully realize their potential.	System-wide mobility benefits realizable (less congestion, more access, etc.); sustainability possible	Data integrated; Data governance detached from profit-/ power-seeking; trustworthy non-self-interested player may find it institutionally easier to integrate data	Data integrated; possibly access by other government departments to provide public goods	Data are secure; flexible entry of market participants; data can be shared flexibly and in trusted formats; few requirements regarding formal institutions and thus attractive solution where governance is weak
Risks/ disadvantages	Mostly commercial; individual personalized data is not always relevant for the objective of promoting sustainability	All other actors are excluded; abuse of power likely	If badly regulated it could stifle start-ups; regulation is slow and can stymie innovation and solutions	Could become an empty or mismanaged shell	Depends on the mandate of the agency; data abuse possible	Data are not integrated centrally; technologies to enable public good provision not yet developed.
Feasibility	High	Plausible	Requires effort but can be done	Plausible	Plausible	Plausible
Example	Let e-scooters off the chain	Google or Uber acquire critical local companies, use data and size advantage to squeeze out competitors	Data sharing between companies and agencies becomes mandatory within specific limits and specified compensation schemes; e-scooters are banned from sidewalks and cars from parking on-street;	A small municipality without its own data-scientific resources asks for help from a foundation to optimize local public transit	Ayalon Highway Ltd. becomes the de facto clearing house for smart mobility data	Commuterz is a start-up that provides blockchain solutions for car-pooling for otherwise non-trusting entities. Specific opportunities for exporting blockchain infrastructures into Low Income Country Cities with a less incumbent legacy system
What to do to get there	Nothing, it happens automatically	Could also happen automatically	Coordinate and implement smart mobility governance between state-wide and urban ministries and agencies	Institution building	Empower a government agency	Support interventional pilot programs; fund technology-based research

The various options for an IDP may appeal to different audiences. To avoid gross misuse and enable free market entry for start-ups, some public action should be implemented to provide an IDP as a service to various constituencies. This could happen under a regulatory regime, a government-controlled IPD, or via a data trust.

The experience of Alphabet's Sidewalk Labs is instructive here. Sidewalk Labs is developing a waterfront city district in Toronto, Canada, engineering the new district with all kinds of smart data. The main obstacles to advancing the project are that residents do not trust the company and the municipality does not have the capacity to govern the data interface itself. A data trust would solve this conundrum. As a non-interested institution, trusted with the data of the new district's residents and infrastructure, it could serve as an interface between the company, the municipality, users and citizens.

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Policy action towards designing an integrated data platform

For the Smart Mobility ecosystem in Israel the following next steps are recommended towards implementing an IPD.

First, an expert workshop with practitioners engaged in similar efforts should be held. That could involve data engineers from places where considerable work is being done to develop IDPs for smart mobility or similar projects, e.g. from Los Angeles, New York, Helsinki, London, and Berlin. It would also integrate the substantial technical expertise already existing in the Israeli ecosystem, for example in the design of synthetic data (MDClone) or the use of blockchains in car-sharing (commuterz.io). The goal of the workshop should be to evaluate different design options and bring further technical expertise on board.

This workshop could take place in January 2020.

Second, smart-mobility data providers and users should be invited to a stakeholder workshop to present several IDP scenarios and flesh out opportunities and risks. Mechanisms for generating trust and serving diverse interests should also be discussed. The goal should be to identify conditions for participation and preferred design options and generate buy-in from stakeholders of the planned IDP. The design of this workshop calls for a high degree of political sensitivity to ensure that the various interests are successfully navigated.

Third, a founding document of the IDP should be written that reflects the evaluation criteria and the feedback from the two workshops. This document should reflect design principles and goals that are permanent. And it should also specify technical rules and implementation processes that are subject to learning and will change with experience.

Fourth, a pilot that is intended to be scaled up towards an IDP should be implemented. A pilot would enable rapid learning and make the best use of the scarce time to deliver on the IDP. The pilot could, for example, provide synthetic data based on the statistics of several existing datasets and, as an open-access resource intended for use by start-ups, established business, research and administrations, it could evaluate the use of this data. The pilot could also aim to specify the data qualities most useful for policies underpinning the reduction of congestion (the "going green"/"alternative" program[26]). In the meantime, the funding, location, and design of the IDP could be worked out in detail and implemented.
A governance board for the IDP should reflect the diversity of its stakeholders and guard the foundational document of the IDP. The IDP

should operate as an actively learning institution that continually learns from its shortcomings. An active collaboration with similar institutions and attempts in other countries could successfully leverage the full potential of an IDP, especially if resources are limited.
While one of the IDP's goals is to allow new start-ups thrive in the ecosystem provided by access to data, through fostering start-ups as an export product, the IDP may itself become a model to be emulated in other countries and offer its services in institutional data governance.

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Fuel Choices and Smart Mobility Initiative

The Fuel Choices and Smart Mobility Initiative, Israel's national program for alternative fuels and means of transportation, was launched in 2011 as a joint governmental effort of ten ministries, headed by the Prime Minister's Office. The Initiative aims to establish Israel as a global center of know-how and industry in alternative fuels and smart mobility.

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