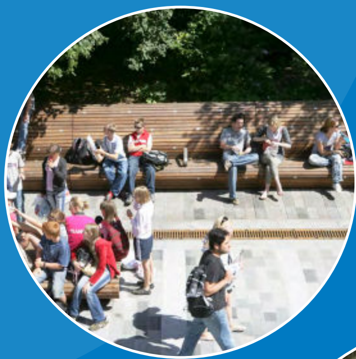
The taxonomy of engagement spaces



Topsector Logistiek

Colophon

The taxonomie of engagement spaces

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Roundabout front page: www.veiligverkeer.be

Management summary

Managing scarce, often commonly available, resources to achieve an optimal use of these resources is a challenging task in a complex system:

- Autonomous actors take their own decisions, based on local and limited knowledge, limited time, and inadequate models.
- The definition of "optimal" is dependent on who is answering the question and might be contradictory with someone else's definition.
- The creativity of actors to deal with problems and challenges is a source of innovation that needs to be tapped, not capped.

The commonly applied strategies are: laisser-faire ("free market") on one hand, and centralized "command and control" on the other hand.

The disadvantages of centralized command and control are well known: useful when there is an immediate crisis, but very ineffective when continued over a longer period of time ("plan-economy").

The laisser-faire approach is upon a closer look a specific example of an engagement space:

> *Virtual or physical space in which process hierarchy is used to enable many autonomous actors to mutually coordinate their interactions and optimize the usage of scarce resources.*

A simple example of an engagement space is a roundabout, or a 4-way stop: the drivers who meet at a crossing engage with each other on the physical, delimited, and designed space. They use simple rules to cross paths safe and fast. The command and control alternative is the use of traffic lights controlled by a computer.

The design flow in this case is:

- designing types of roundabouts and the rules of engagement;
- building a specific roundabout type in a specific location;
- using the roundabout and the rules of engagement in a location as a driver.

This example shows that "laisser-faire" is a misnomer: the emergent positive effect is the combination of the autonomy of actors with using agreed upon rules of engagement in a defined environment. This means that the design of the engagement space influences the emergent effect.

There are multiple types of engagement spaces already observable, or in a design or experimental stage. The market economy is the prime example, constantly being modified to adapt to changing circumstances, innovation in technology and shifting priorities.

The potential for applying engagement spaces to coordination challenges has been increased significantly with the advent of networked (handheld) IT-systems and mobile communications. The concepts of "tokens" as a non-monetary carrier of value and information adds to the breadth of potential solutions.

The design of an engagement space is currently more an art than a science. There is a lack of mathematical tools to predict emergent behaviour in complex systems with multiple independent actors, even with a limited number of actors. At the same time there is a lot of research into the tools and concepts to deal with systems that have a large number of agents, and to simulate complex systems.

The design process therefore has to use both heuristic modelling and extensive iterative simulation to achieve a stable set of rules of engagement.

Many potential use cases have been identified that have a high societal value.

This paper describes a proposed taxonomy of engagement spaces, as the first step in developing a systematic approach to designing engagement spaces, fit for purpose.

Table of content

1 Managing scarce resources

Managing scarce, often commonly available, resources to achieve an optimal use of these resources is a challenging task in a complex system:

- **Many autonomous actors**
  Each actor operates with its own objectives and motivations, which can lead to conflicts or coordination challenges: the definition of "optimal" is often not agreed upon of shared between actors and may even be conflicting.

- **High specialization, therefore very interdependent**
  Rapid advancements in technology lead to differentiation and specialization: interdependencies between different actors increase.

- **Unpredictability as well as potential for innovation**
  There is a lack of mathematical tools that predict the behaviour of even simple systems with autonomous actors, let only more complex systems. The so-called "emergent" behaviour of a system can be observed, simulated but up to now hardy predicted[1]. The creative energy of actors combined with technological advancements lead to innovations that should be welcomed.

- **Constraints, such as legal and financial**
  With the increase of cross-border activities, legal frameworks are increasingly complex and layered (e.g. international guidelines, EU and national laws). Also, the emergence of new technologies lead to additional regulation, to deal with complex issues such as privacy, cybersecurity and AI algorithms. The same applies to the financial context: business models for new technologies rely on complex, globalized supply chains.

The main strategies that are applied to solve this challenge are "command and control", and "let the free market find solutions".

1 *There is a lot of research activity using agent-based systems, simulation tools and other methods to harness complex systems. This body of knowledge is expanding and will help to design complex systems: the mathematical "silver bullet" is however not yet invented.*

2 The limitations of command and control

A commonly applied strategy to allocate resources is centralized "Command and Control". In this strategy, the system design approach is to engineer a system, structured around a functional hierarchy. Within such a hierarchy, there are typically tasks (i.e. objectives that need to be accomplished within the system), which are then decomposed into subtasks (i.e. smaller, more manageable units). A combination of actors and mechanisms then ensure that execution is coordinated, ensuring that subtasks have access to the right resources in order to achieve the main objectives efficiently.

The disadvantages of centralized command and control are well known: it is useful when there is an immediate crisis, but very ineffective when continued over a longer period of time ("plan-economy").

This is the case because the demands are challenging: rich, customized and fast responses are expected, the complexity of tasks is growing, and the scale of the system increases. This means that it becomes increasingly difficult to maintain the desired level of quality against reasonable costs, or to adopt fast enough to changing circumstances (low latency).

In a system structured around functional hierarchy, costs and latency can explode for a number of reasons:

- The number of decisions grows exponentially;
- Information requirements to be able to do the task grows exponentially;
- Information is often "lost in translation": it is simplified or loses its context;
- Models that drive decisions are inadequate or too simple;
- There are slow or even missing feedback loops to correct the models and decisions;
- There is a lack of innovation, due to a monoculture;
- There is high overhead to deal with complexity.

As such, the effectiveness of central functional steering is limited and expensive in complex systems. Its application might be necessary in crisis situations, where rapid decision-making and clear commands are necessary, but in other cases alternatives might be more suitable.

3 The market economy as alternative to central planning

Laisser-faire, or in more popular terminology "the free market" or "market economy" is the alternative solution to a centrally planned economy that western democracies have successfully adopted and refined. Independent actors make their own decisions and the sum of their actions ("emergent behaviour")[2] is assumed to give a better system performance than command and control.

Laissez-faire is sometimes mistakenly defined as 'no interference'. This is incorrect: a functioning market needs rules of engagement like corporate law and a price mechanism, and value mechanisms (fiat money, fractional reserve banking, central banks etc.). The history of our economies shows constant discussion and (successful and failed) experimentation with new structures and rules to correct unwanted effects, or to adopt to changed environments or changed priorities. The shift to fiat money from gold backed currency, or the introduction of regulation on competition are examples of these modifications to the rules of engagement.

One of the core rules in a market economy is the free setting of prices. In economic theory, the price mechanism is introduced as a way to coordinate the actions of free agents. The price signal is used by these free agents to allocate resources and stimulate innovation and productivity.

A price mechanism, however successful it may be, has limitations when dealing with scarcity:

> *The general idea is that if demand exceeds supply, the price is increased, which reduces demand until a new balance is reached. The increased price drives actors to search for main alternatives, and/or develop new supply.*

If it is very difficult to use alternatives (e.g. because it is expensive, new investments are needed, or time is needed) the actors with the lowest buying power are forced to spend excessive portions of their budgets on increased prices, or reduce their demand. An example of this is the natural gas shortage that Europe faced in 2023. Households with natural gas heating had hardly any alternative options and therefore they were forced to accept the increased prices or reduce their gas use.

If the indirect value of purchase is different between actors, and their possibility to pass on the price increase is different, the effects are exacerbated. This almost happened with diesel shortages in 2023. Transport of groceries to shops will continue, even with a 1000 % increase in price for fuel, because the costs of not delivering groceries is much higher that the added costs of fuel. The same fuel price would have been crippling for actors with lower buying power, such as farmers, SME's, or private owners of diesel cars.

On the other hand, the increase in price is a boon for suppliers: their profit margin explodes. This attracts outside speculators with deep pockets and is an invitation to restrict demand even more artificially to increase the price even more, especially if the constraints on new supply or alternatives are high.

Through this mechanism, a relatively small mismatch between demand and supply can lead to a sizeable increase in price, paid by everyone involved. The marginal costs (i.e. the total increase in price x volume) for this mismatch can be excessive, macroeconomically speaking.

The challenge is to find additional or alternative rules of engagement to deal with situations of scarcity more effectively, before reverting to command and control solutions: command and control should be the last resort, "market based" solutions are preferred by many.

2 Or "invisible hand" of Adam Smith

4 Engagement space: rules and room for creativity

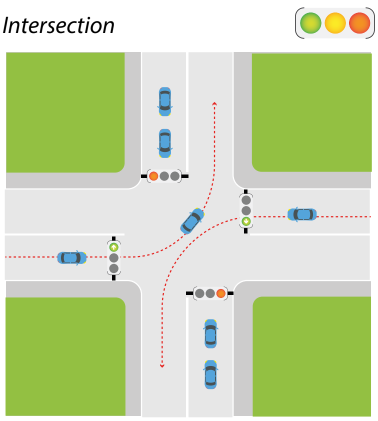
The market economy with a price mechanism is upon a closer look a specific example of the general concept of an engagement space:

> *Virtual or physical space in which process hierarchy is used to enable many autonomous actors to mutually coordinate their interactions and optimize the usage of scarce resources.*

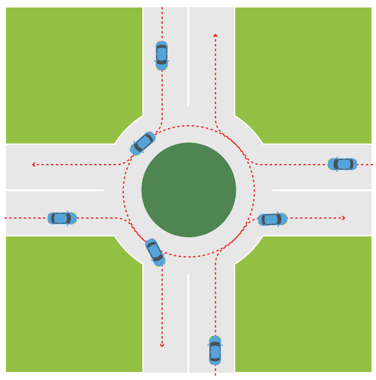
A simple example of an engagement space is the way to safely allow traffic to navigate road crossings. The command and control solution is to add traffic lights to an intersection: drivers must obey the lights. They are not allowed to do anything else than follow the commands.

The alternative approach is the roundabout, or a 4-way stop in the US. The drivers who meet at a crossing engage with each other on the physical, delimited, and designed space. They use simple rules to engage in the space, make local decisions and cross paths safely and fast. This is event-driven: the event of arriving at an intersection prompts drivers to take action.

Intersection



Roundabout



In practice, the drivers use the rules as a baseline and adapt them to the circumstances, instantaneously inventing solutions for situations where the rules do not give an algorithmic answer. Humans apply rules but invent principle-based new solutions on the spot if needed. Successful inventions (e.g. honking, flashing headlights, waving hands, etc.) get copied and added to the common repertoire of drivers. This leads to the "code of the road" that is slightly different per region. This local creativity is the reason why autonomous vehicles have trouble navigating these engagement spaces: the rules do not cover all situations.

The emergent positive effect is the combination of the autonomy and creativity of the actors, using agreed upon rules of engagement in a defined environment and adapting them locally. This means that the design of the engagement space influences the emergent effect, including the room for innovation and local adaptation.

An engagement space design follows a so-called process hierarchy.

5 Creating scalability and flexibility by using process hierarchy

In a process hierarchy, higher level actors define the rules and preconditions that are necessary for actors to achieve specific objectives, rather than predefining tasks and subtasks. In the context of complex system design, this has the following characteristics:

1. **Design of processes and interaction rules**
   a. Higher level processes shape what the overarching goals and constraints should be for lower-level processes. This is done in a generic way, leaving autonomy for actors that operate in lower-level processes. They provide these actors with a typology, with the aim of creating boundaries and ensuring standardization. Rather than predefining subtasks, they guide actors in shaping their own implementation.
   b. Higher level processes specify the responsibilities for maintaining and updating the process, in order to ensure its effectiveness and allow for innovation.

2. **The implementation of processes is done locally**
   The implementation of the processes is done locally, so that local actors have the flexibility to make context-specific decisions. In this way, they can tailor their processes to their unique circumstances, while adhering to the overarching interaction rules. Local actors also facilitate the physical, digital and governance infrastructure. This allows tailoring of the infrastructure to the specific needs of the local actors.

3. **Actors interact with each other**
   Central in a process hierarchy is interaction between actors: within a process they can work together to mutually achieve an objective. This is different than a functional hierarchy, which does not easily allow for interaction between actors, if they work towards different subtasks. Actors in a process hierarchy are stimulated to coordinate their efforts to achieve goals. They operate within the boundaries that are set by the higher layer processes but retain autonomy in coordinating their efforts with others.

Commuting in Japan and the Netherlands: the same kind of transport and level of agreements, but completely different behaviour.

The previously mentioned traffic management example sheds light on the difference between functional and process hierarchy. A traffic control system with traffic lights at an intersection can be compared to a functional hierarchy. It operates based on a centralized control system. This centralized system manages the timing and order of cars passing the intersection. The individual cars have little autonomy: they have to adhere to predefined rules. Green means go, yellow means caution, and red means stop.

While advancements in traffic control system technology now increasingly allow for flexibility, this solution is typically rather static. That is, changes to the timing and sequencing to adjust to changing circumstances (e.g. varying traffic volumes) typically require adjustments to the software or the hardware by traffic engineers.

On the other hand, a roundabout can be compared to a process hierarchy. Instead of a centralized control system, in which road operators define the exact flow of traffic, road operators merely predefine a set of interaction rules. That is, those entering and exiting the roundabout yield to traffic already circulating on the roundabout[3]. Traffic flow is then guided by the engagement between local, individual drivers that enter, circulate on, and exit the roundabout. This allows for more flexibility: traffic dynamically adapts to changing circumstances, such as varying traffic volumes.

It must be noted that in this example, the roundabout solution will stop working once there is no more road capacity left to negotiate about (e.g. in case of too high traffic volumes). In that case, it might be necessary to fall back upon a centralized steering system (in this case a police officer giving commands). This could be seen as a "crisis situation", in which case centralized command and control can still be beneficial.

In the case of complex systems, a process hierarchy offers a number of advantages:

- **It allows for scalability**
  Within a process hierarchy, decisions are implemented by decentralized, local actors. This eliminates the need for higher level actor to manage decisions by themselves; they merely manage the interaction rules. As a result, when the number of decisions increases, there is little to no extra work for central actors, as the rules stay the same. In this way, a process hierarchy allows for scalability.

- **It allows for innovation**
  Within a process hierarchy, local actors retain autonomy to find their own solutions within the predefined boundaries. This encourages innovation: it creates space for finding new ideas or approaches to achieve their objectives more efficiently and effectively.

- **It allows for flexibility**
  Because local actors retain autonomy in a process hierarchy, there is a quick feedback loop. That is, they are able to quickly adapt to changing circumstances, by choosing different actions that still fit within the boundaries that are given by interaction rules.

The challenge is how to design and maintain such engagement spaces. The first step is to create a taxonomy.

3 In a famous example, the design rule as observed in the UK by Dutch authorities was mistakenly copied initially as "traffic on the right has right of way", instead of "traffic on the roundabout has right of way". In a righthand drive country this is equivalent, but in a lefthand drive country this rule leads to a roundabout that is difficult to navigate. It still exists in the city of Nijmegen.

6 The taxonomy of engagement spaces

Based on our own investigations, a taxonomy for engagement spaces is created.

This includes 5 categories:

1. What should the *engagement space* itself, in which interactions between participants occur, look like?
2. What should the *accounting* system look like, i.e. is the exchange of values in the engagement space tracked and managed, and how?
3. What should the *governance* of the engagement space look like, i.e. what actor(s) should determine the rules for how the engagement space operates and how the participants interact?
4. Who should *enforce* the rules that have been determined?
5. What should be the *legal context*, i.e. what is the nature and scope of the laws that apply to the engagement space?

It can be found in the *Connekt engagement spaces classification matrix* below. This taxonomy is seen as the first step in being able to design engagement spaces, fit for purpose.

DISTINCT OPTIONS

Engagement space	Accounting	Governance Rule setting	Enforcement	Legal context
☐ Physical	☐ No	☐ Individual (e.g. asset owner)	☐ By individual actor	☐ Public law
☐ Digital	☐ Yes	☐ Communal (e.g. all participating players)	☐ By neutral party	☐ Administrative law
☐ Public owned	☐ If yes, token that can't be monetized			
☐ Private owned	☐ If yes, token that can be monetized			
☐ Closed (Only players allowed)	☐ By individual actor			
☐ Open (Mix of players and non-players)	☐ By neutral party			

7 Design of (potential) engagement spaces

There are multiple types of engagement spaces already observable, or in a design or experimental stage. The market economy is the largest and most complex example, and roundabouts are another simple physical example.

The potential for engagement spaces has been increased significantly with the advent of networked (handheld) IT-systems and mobile communications. That is, it vastly expands the capabilities and the reach of engagement spaces, making the exchange of value more accessible and dynamic. The concepts of "tokens" as a non-monetary carrier of value and information adds to the breadth of solutions. Tokens that merely hold value within one specific system (e.g. they can only be used by inland vessels to get priority at a lock, and for nothing else) can solve some of the earlier-mentioned issues that the free market currently faces. That is, it prevents that parties with large buying power can make more use of scarce resources and start speculating on it.

The design of an engagement space is currently more an art than a science. There is a lack of mathematical tools to formally predict emergent behaviour in complex systems with multiple independent actors, even with a limited number of actors. At the same time, there is a lot of research going on into the tools and concepts to deal with systems that have a large number of independent agents. The same can be said for simulators for complex systems, benefitting from the advances in computing power.

The design process therefore has to combine heuristic modelling, good simulation and extensive testing to achieve a stable set of rules of engagement.

We have listed a number of (potential new) use cases where this idea might lead to new solutions.

- A workforce collectively making and updating their own workforce planning.
- Carriers exchanging their distribution centre loading and unloading slot times among themselves.
- Street residents collectively regulating transportation movements in their street.
- Inland vessels negotiating their order at a lock.
- Shared mobility users contributing to fleet rebalancing.

A workforce collectively making and updating their own workforce planning

This engagement space has been implemented to satisfaction of all stakeholders.

Typical current situation

A planning department, for example of a hospital, creates the workforce planning based on the task to be carried out and the availability of the employees with the right skill set. A complex task in itself. The employees' preferences for shifts, like preferrable dates, times, or working other colleagues are not taken into account. Once the planning is created, the planning department must handle all change request themselves. The planning department does not have the time to evaluate alternative options. As a result, change to the planning an often not possible. This leads to lower employee satisfaction and impacts the quality level of the work carried out.

Engagement spaces alternative

There are workforce planning systems that let the employee plan themselves. Planning is done in two rounds. In the first round, employees can select their desired shifts. If multiple employees are bidding for the same shift, the employee with most tokens is granted the shift. Tokens can be earned. For example, by helping colleagues out by accepting their change request. Or by accepting a shift in the second round. During the second planning round, shifts are offered that are not planned in the first round and are therefore not desired. By accepting it, an employee helps out the collective planning and earns tokens. The result is that employees are happier. It is better for them, better for the service in the hospital, and better for the hospital manager (because of a higher employee retention rate).

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Carriers exchanging their DC loading and unloading slot times among themselves

This type of engagement space is being investigated for trials in ports and DC's.

Typical current situation

Slot management at distribution centres is done to optimize the workflow in the distribution centre. Carriers are given static time slots at which they must deliver and/or collect goods. In case a slot is missed, a new slot can be hours or even days later. This results in inefficiency in the warehouse (i.e. idle time of workforce and capacity) and inefficiency at the carrier (i.e. long waits for a new slot or being extremely early to avoid missing a slot). Additionally, the carrier may receive a financial penalty for missing a slot.

Engagement spaces alternative

Slot planning is created and coordinated by the operator of the DC. If carriers find out that they are going to be too early or too late, they can request an alternative slot. If a match can be created between two requests, then the slot times are interchanged. This costs the requesting carrier a token, and the carrier accepting the time change is granted a token, which they can use in similar future situations.

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Street residents collectively regulating transportation movements in their street

This type of engagement space has been proposed in brainstorms on city traffic management.

Typical current situation

To avoid nuisance for residents, local governments set strict time windows for the supply of local businesses. The combination of time windows, opening times of local businesses, and delivery frequencies result in only partially filled vehicle driving around inefficiently planned routes. While the goal was to minimize nuisance of logistics vehicles driving around, the result is more vehicle kilometres.

Engagement spaces alternative

The total amount of transport movements in and out the area is maximized by a collective agreement of the residents. A transportation company that wants to enter the (city centre) area must pay with a token. Tokens are distributed among the local business based on a measure collectively agreed upon by the residents. The number of possible deliveries now become scarce and local business need to adapt. For example, by reducing the number of deliveries per week or per month, or by combining deliveries with other businesses.

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Inland vessels negotiating their order at a lock

This type of engagement space has been simulated successfully.

Typical current situation

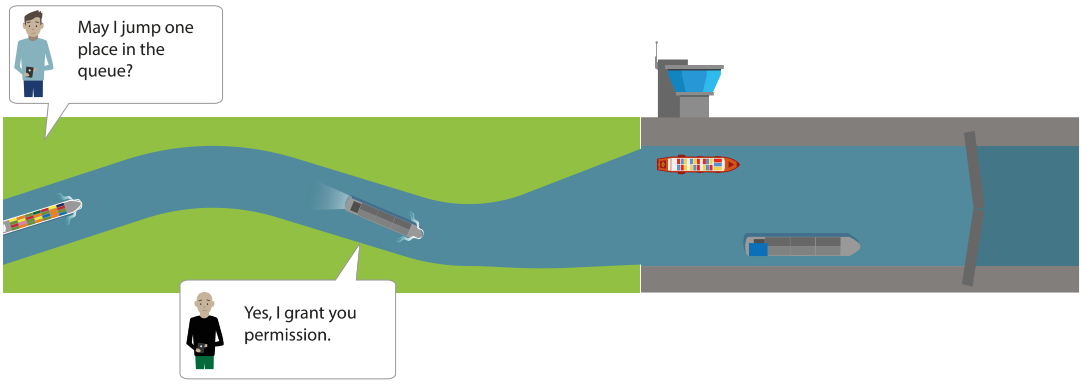
Inland vessels arriving at a lock are being served on a "first come, first served" basis. This sequence may not be the most optimal on a system level. For instance, if a vessel pushing to meet a deadline is at the back of the queue, while multiple vessels in front of the queue have plenty of time, it would be beneficial if the order is changed. However, there is no mechanism that is acceptable to the vessel owners: a command and control solution would meet much opposition.

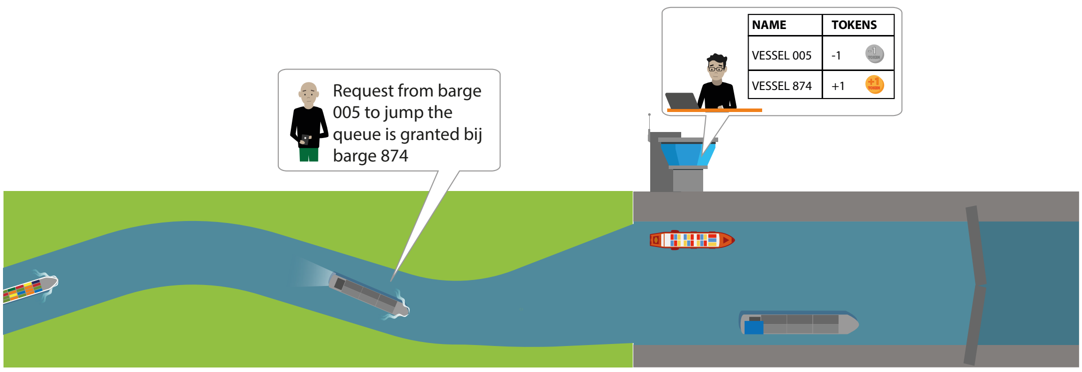
Engagement spaces alternative

The simulation showed that a simple mechanism has much potential and can be used without having to incorporate every vessel. The rule successfully tested is:

- If you want to jump one place in the queue, you must ask permission of the vessel in front: the captain of that vessel can refuse or accept, for any reason
- If permission is granted, you must give up one token
- If you allow a vessel to jump the queue, you receive a token
- The waterways authority keeps the score of tokens per vessel and the transfers, and the lock manager applies the changed priority

The visibility of the score, the possibility to use a token later at a different lock, the possibility to refuse priority to a bad actor, the impossibility to free-load and the simplicity of the rule makes this an attractive solution.





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Shared mobility users contributing to fleet rebalancing

This type of engagement space has been applied by mobility service provider Check to some extent. In the example below, it is expanded.

Typical current situation

to allow an effective system of shared vehicles (e.g. scooters or cars), the vehicles need to be as close to potential users as possible. There is however a mismatch between the popularity of origin and destination locations: some areas are more popular as trip origins (e.g. city outskirts), whereas others are more popular as destination (e.g. malls or city centres). Moreover, municipalities might prefer or mandate vehicles to be left in certain areas more than in others. As a result, mobility service providers rebalance the fleet using vans, putting a burden on scarce road capacity.

Engagement space alternative

users are incentivized to contribute to fleet rebalancing through tokens. If they choose to pick up a vehicle from a popular origin and leave it on a popular destination, this costs a number of tokens. However, if they choose to use less popular origins and destination, they earn a number of tokens. A coalition, consisting of the municipality and the active mobility service providers, provides these tokens. As a result, they can be deployed cross-platform, i.e. for multiple mobility providers. Users have the ability to buy extra tokens (e.g. through a subscription), if they wish to.

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8 Further exploration and application

As the given examples illustrate, we see a large potential in the structured exploration and application of the idea of an engagement space. Especially for complex challenges, where many actors need to collaborate to effectively allocate scarce resources, engagement spaces can be the solution. It will enable improved collaboration mechanisms to maximize the societal value created.

The next steps are to apply the taxonomy in practical use cases and develop a structured design and evaluation process. Connekt will actively facilitate this process, and ensure that engagement spaces are further developed and applied.