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# Joint Road Forward: a new set of tools for including excluded perspectives on transport infrastructure

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**Abstract.** Planning of transportation infrastructure is built upon an established set of planning methods to estimate the need for and specifications of roads, amongst others. The abstraction from the real world as needed for applying clear planning tools has grown to considerably differ from the complex urban fabric of activities underlying the transport demand, such as food distribution, commercial activities, education networks, health, etc, especially in busy metropolitan areas. Inclusion of new parameters and use cases in design poses new methodological challenges. The socio-cultural context of urban areas provides for meaningful explanations for the use of urban infrastructure. The cultural context determines the expectations placed on the infrastructure by the people. For example, accessibility for the elderly and children, security and availability.

Rapid urbanisation and increased economic inequality in cities has provided additional parameters to understand the longevity and contribution of transport infrastructure. The use of new methods such as the availability of real time data, sensor based data and additional social network analytical methods can provide new insights to understand the needs of the urban masses. Transport infrastructure needs to cater to local needs and become part of a larger ecosystem of a city. In this work we outline a new methodology to use games and simulations based upon city sensing to include stakeholders ignored by the traditional planning processes.

## Introduction

The global urbanisation trend generates an increasing need to transport people, goods and utilities in support of the socio-economic activity of cities. As witnessed daily in many urban environments, the traditional transportation system design methods for road, rail, public transport and other modes have shown significant challenges in delivering inclusive and sustainable designs.

Historically, transportation infrastructure designs have been evaluated as economic productivity engines. The identification of the direct and indirect users and their motivations to use infrastructure has been limited; these factors are even less reflected in the design options considered both in Western Europe and India. Conventional data capture and data analytics have contributed to this limitation.

Participatory planning techniques are considered as one of the ways to account for the lack of involvement from certain sections of the society. Participatory tools such as gaming

simulations and crowd-sourcing platforms can involve previously excluded user groups and layers of society for design, creation and operation of urban infrastructures, both in the Western and Indian contexts (Meijer, 2015 (power of sponges in S&G).

We propose these participatory data-driven tools will bring together the intentions of the (excluded) users and the response of solution providers within an institutional context to achieve collaborative designs for mobility infrastructure. We summarise the objectives of the tools as follows:

1. The quality and quantity of user mobility pattern and requirement will determine the understanding of mobility preferences.
2. An inclusive and participatory design method will improve the quality of the infrastructure and mobility design and will promote buy-in as it will account for stakeholder preferences. Participatory methods will involve and consider the interests of the entire population, including the poor, less visible and vulnerable user groups;
3. The sustainable and adaptive operation of the infrastructure depends on rich user feedback.

A variety of large urban contexts, products, societal needs and institutional structures will provide workspace richness. We limit our scope to (i) mature environments, such as the Dutch Randstad (7.1million inhabitants, 8,300 km<sup>2</sup> - 4,300 km<sup>2</sup> urban); (ii) rapidly growing city such as Bangalore (9.6 million inhabitants 1,300 km<sup>2</sup>); (iii) and an ideal-imaginary tabula-rasa city.

In the following sections we explain the use of the PSI framework of design while considering the city as a system governed by P (product), S (social) and I (institutional) spaces. In the following sections we demonstrate a naïve example to adapt the existing technique of Use Case based reasoning and analysis to mine and represent the different transport related requirements. We then briefly explain the how the outcome of the data model will be used to design simulations and gaming simulations that can be used among the stakeholders. We conclude with the outline of the framework that we will use to create a more inclusive design methodology for mobility in a city.

## **Conceptualising a participatory approach to design tools for urban environments**

We identify the following as key components for our approach:

1. Data acquisition, using existing data sources, crowd-sourcing and data proxies, to explain the temporal mobility patterns and the mobility requirements of a representative urban population; followed by Mobility mining and modelling to map the collected data to mobility preferences;
2. Iterative design of computer-based simulations and participatory gaming simulations by the application of the Product, Social and Institutional (PSI) design framework. The outcomes will be different infrastructure designs and their associated implementation roadmaps;
3. Evaluation of the outcomes to develop implementations roadmaps sensitive to the urban contexts in The Netherlands and India.

### ***PSI Framework for design of participatory tools***

The PSI framework conceptualizes design as taking place in three related but qualitatively different spaces: a product space, a social space, and an institutional space. The product space describes what is being designed, whereas the social space and institutional

space characterize the people involved in designing and the coordination mechanisms used respectively. It does so by characterizing these spaces using three dimensions. For instance, if we would like to describe the P-space, we use the dimensions of structural complexity, amount of disciplines involved and the knowledge availability to describe how complex the design task is. Key to this framework is that these spaces impact each other constantly: changes in the design in the product (P-space) create the need to include new actors with different perspectives and languages (S-space) and instigate the design of suitable institutions for effective coordination of design activities (I-space). In table 1 we provide an overview of the three spaces and their three dimensions.

Table 1: PSI framework.

<b>Space</b>	<b>Populated by:</b>	<b>Dimension</b>	<b>Explanation</b>
P (product)	Technical infrastructure, software, operators, operational procedures	Structural Complexity	Interdependence between system components
		Amount of Disciplines	Amount of qualitatively different disciplines involved in designing the artefact
		Knowledge Availability	Completeness of knowledge needed to design the artefact
S (social)	Designers, decision makers, stakeholders	Amount of Languages	Amount of different vocabularies used to describe the artefact
		Amount of Perspectives	Amount of different perspectives on artefact and its functions
		Inclusion	Ease by which actors can enter the S-space
I (institutional)	Rules, Organizational structures, contracts	Strength of ties	Weak versus strong ties
		Coordination Mechanism	Markets, hierarchies or networks
		Knowledge Accessibility	Ease by which knowledge can be accessed

PSI framework serves as a tool for analysis and design of socio-technical systems. In its role as an analytical tool we can analyse the current states of systems; for example, the transport design and operations in a city. The PSI framework helps to measure qualitatively, the relationship between problem of transportation (as defined), the level of participation and inclusion of different stakeholders, along with the rules, structures and contracts that define an organization. The redesign/design of transportation systems to include larger parts of the population would require new data and revealing of new demands on the transportation infrastructure in light of their specific needs.

There is a need for new methods for inclusion, beyond simple surveys, to understand the nature of interaction between the problems of transportation that will emerge which, will impact the interactions between the problem and the institutional space. Reich et al (1993) argue in the design of artefacts that there are varieties of methods are required to enhance participation in design. In Meijer et al. (2011), the use of simulation and games to address complex systems has been forwarded as a method that can enhance participation The rationale is that inherently

games can bring to fore conflicts and constraints across the stakeholders providing a means by which to resolve them by also changing the rules of the game (institutional rules). The papers by Hoogen & Meijer (2015) illustrate the use of gaming simulations in the context of redesign of a section of the Dutch ProRail railway infrastructure operator through gaming. In these papers, they show how the PSI framework guided the creation and use of the games in arriving at a new and innovative solution to the problem. We will be using a similar approach to enhance the participatory aspects of the transport problem.

### **Capturing data from underrepresented groups: Use Cases**

One of the main goals of this approach to transport modelling is to increase inclusiveness to transport infrastructure among all citizens of a city. Traditional models do not take the social context of the stakeholders into account while estimating the travel demand. By including information such as demographics of commuters during peak hours, transport infrastructure can be made more sensitive to the needs of the commuters. However, such a change has to be propagated throughout the transport system, and translates to requirements for different parts of the system. The PSI framework is used to conceptualise the system in terms of the P, S and I space. One of the requirements in order to achieve this goal is to identify the missing stakeholders.

We begin by representing the current transport infrastructure as use-case scenarios and identify the entities as belonging to P, S or I space. We use data about the system from different sources to generate the use cases. We classify our data sources as follows:

- a. Formal data sources: These are data collected by designated official organisations based where the plans and rules are adopted formally as part of rules of the local elected bodies. These include surveys, public consultations, official plans, reports, etc.
- b. Informal data sources: These data sources are either are not directly connected to transport and may require mining or processing to connect them to transport plans. They are newer data sources such as social-networks, sensors, ticketing information, informal surveys, etc. Citizen based data collections can are also categorised here.

*An example representation of some stakeholders and the systems*

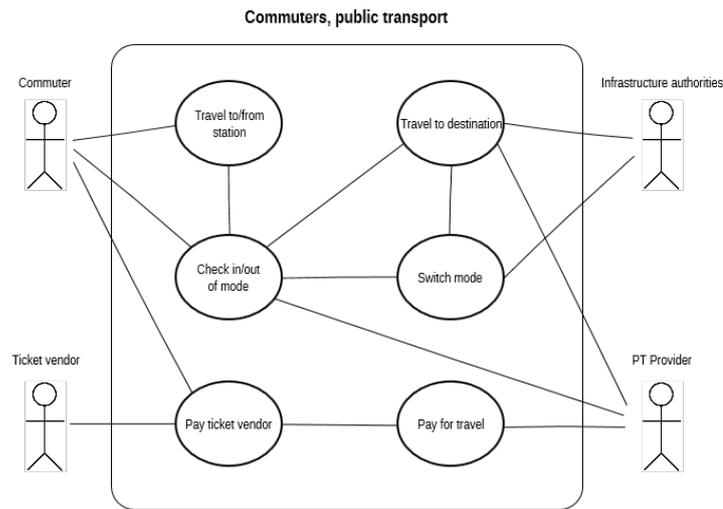


Figure 1. Use case: Commuters on Public Transport

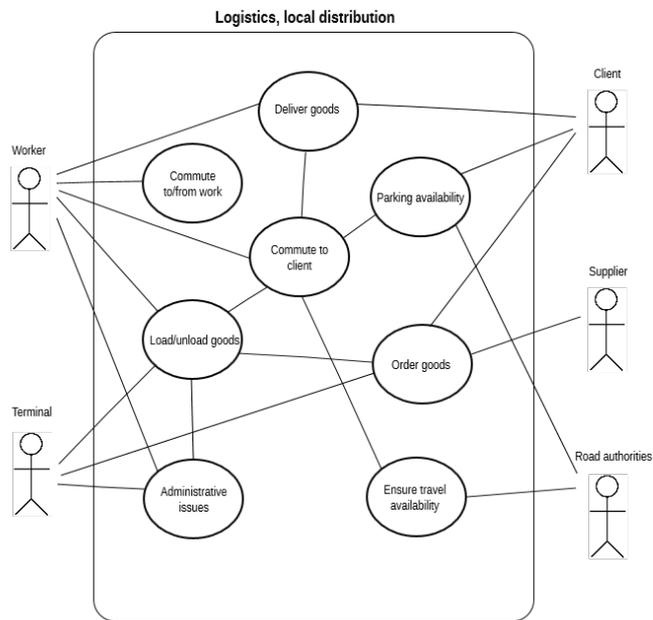


Figure 2. Use Case: Logistics of local distribution

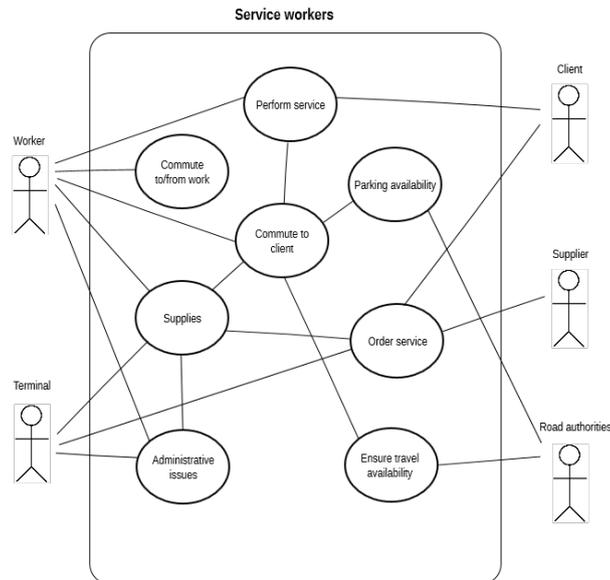


Figure 3. Use Case: Service Workers

In the first use-case diagram, describing cases for the commuter, a regular trip starts with travelling by choice of slow mode to a station. At the station the user ensures having a valid ticket for the trip, either by purchasing it from a ticket vendor upon arriving at the station, or by paying for it in advance. The commuter then checks in to the chosen mode of travel, travels to the intended destination, checks out and either checks in to the next mode of travel, repeating the process from check in over again, or continue using slow modes to intended final destination.

The roles of the other actors are for the ticket vendor to supply the commuter with a valid ticket and assure that the public transport service company is paid. The public transport company needs to provide adequate service, bringing the commuter to their intended destination. This is supported and made possible by the infrastructure authorities.

The second diagram describes a logistics operation for local distribution. The worker starts by commuting to the workplace by his/her mode choice. Worker proceeds to load or unload his/her service vehicle and commutes with the service vehicle to the client. At the client's the worker parks his/her trucks at a loading dock and proceeds to load/unload goods. The worker then either heads back to the terminal or proceeds to travel to the next client. Upon returning to the terminal the worker either proceeds to load/unload the service vehicle and head to the next client, or finishes the day and commutes back home.

The roles of the other actors in this case is for the terminal to ensure that ordered goods are available, or order them from the supplier. They also ensure administrative issues and the handling of goods are taken care of. The client orders a truck to deliver goods, either to or from them, handled in communication with the terminal. The infrastructure authorities should ensure travel availability by maintaining roads and other infrastructure needed. They also, together with the client, need to be able to supply adequate parking spots.

The actors in the final diagram describe service workers, are tradespersons needing a service vehicle to perform their work. The terminal (people and facilities) where a worker travels for any administrative issues, or to load/unload tools or materials required for their work. The client is an organisation or individual ordering service from a Terminal. The supplier, a

manufacturer or other entity able to supply goods of a desired type. The Infrastructure authorities, governmental and private organisations that guarantee adequate commuting infrastructure.

Although the scenario is similar to that of logistics, here, the worker is the service vendor and is responsible for his/her vehicle. The roles of the other actors in this case is for the terminal to ensure that ordered necessary equipment is available, or order them from the supplier. They also ensure administrative issues and the handling of equipment are taken care of. The client orders a service from the terminal. The infrastructure authorities should ensure travel availability by maintaining roads and other infrastructure needed. They also need to be able to supply adequate parking spot availability.

## **Gaming and Simulations for scenarios with participatory approaches**

The use-case based analysis describes the current system and is used to develop the model for mobility for a given city within the PSI framework. One of the key aspects for the PSI based approach is to identify and model the interactions between P-Space, the S-Space and the I-Space. Meijer et-al present the use of gaming simulations to capture the interactions in a complex environment. We employ the use of gaming simulations in order to capture the interactions between the PSI spaces.

The current model is intended for use in multiple social contexts. We thus, describe a game design methodology which can be used to design specific games for specific social contexts in order to capture intersections with respect to mobility.

### ***Participatory approaches in modelling travel behaviour***

Participatory methods can change the scope of S-space by narrowing down specific aspects related to transport demand and infrastructure. We employ this in design of participatory gaming simulations that can capture specific data for use in transport and mobility modelling.

Participatory process strives to create a space for participation for all the stakeholders where they will be able to negotiate with the system and fellow stakeholders, to collaboratively design the system components. The idea is to build systems bottom up and employ the knowledge of the stakeholders to identify constraints that are not captured at the higher levels. The participatory space is modelled to simulate the social and institutional interactions, while providing a controllable space to observe the interactions with stakeholders. Thus, the observations from the gaming simulations can be analysed using the PSI framework to identify design requirements for transportation infrastructure.

**Identifying the stakeholders** Based on the role the stakeholder plays in the transport domain, their experience, behaviour, influence and knowledge can vary.

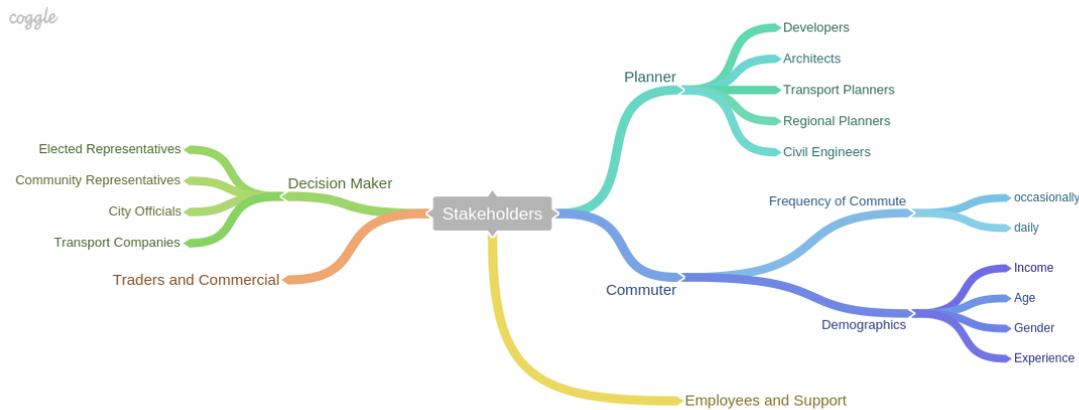


Figure 4. Map of possible stakeholders

A stake holder can be one of the following as also depicted in Figure 4:

- a. *Commuter*, frequent, rare. Commute behaviour will also vary based on demographics, such as age, gender and affordability, etc.
- b. *Planner*, planners can be from transport planners, regional planners, architects and developers
- c. *Decision makers*, influential people from the community, elected representatives, city officials, transport companies, etc.
- d. *Employees and Support Staff* who are associated with running, maintenance and upkeep of the infrastructure.
- e. *Traders and commercial establishments* who rely on the transport infrastructure to run their business.

Apart from the different classes of described above and in Figure 4, there is further diversity in the language and experience for each stakeholder. In order to get a meaningful participation each stakeholder has to feel.

- a. Represented,
- b. Sense of ownership towards the plans,
- c. A sense of responsibility.

Gaming simulations provide an ideal platform to engage with a diverse set of audience while being able to define the means of engagement. Gaming simulations have already been demonstrated as an ideal tool for tackling multiple stakeholder problems (Brandt 2006) and (Muller 94).

Based on the use-case scenario, specific stakeholders can be identified, for the given Outcomes for us include acceptable levels of service and affordability, list of stakeholders change and list of issues and behaviour change,

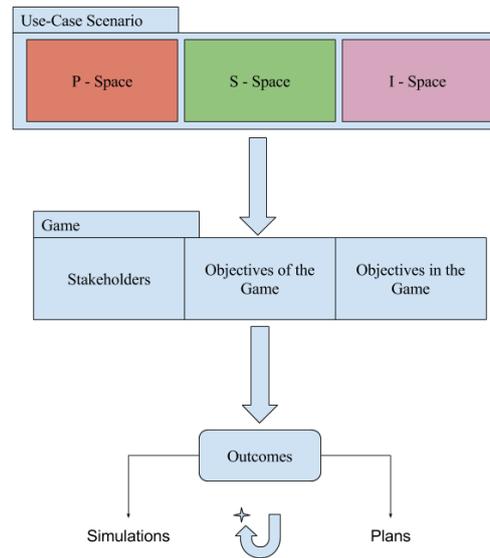


Figure 5. Game development loop

**Design Methodology for design gaming simulations for mobility.** Our objective is to identify the design parameters for a given gaming simulation. In the design of infrastructure, we focus on the estimation of travel demand. We mine diverse sources of data<sup>1</sup>, to capture invisible demand, and build a game simulation on top of this to enrich the data.

A typical gaming simulation would require us to identify three aspects,

1. The target audience, in this case the set of stakeholders
2. The objectives of the game, i.e. the set of interactions under study
3. The objectives in the game, i.e. the set of parameters that define the specific context in which the game is being played.

Figure 5. gives a brief overview of the extraction of the above parameters from the PSI framework.

Microscopic modelling of transport behaviour and demand requires micro information with respect to the interactions of people to the infrastructure. Depending on the combinations of stakeholder, these interactions can be complex. The PSI framework provides a way to handle the complexity by identifying people, institutions and process as fundamental building blocks. Each such interaction is a potential case for a gaming simulation. Based on the use-case analysis, and employing the PSI framework, the process in depicted in Figure 5 can be repeated for modelling the interactions bottom-up.

The availability of micro data especially in the S-Space, determines the number of gaming simulations required. For example, in the case of the Randstad region, the government carries out detailed surveys on travel behaviour of people at regular intervals. Such data can be used in traditional planning and simulation systems, and can be simultaneously represented in the PSI domain. However, the people missing from the survey data have to be captured based on the gaming simulations, thus, requiring one gaming simulation to identify missing stakeholders. In case of Bangalore, India, there are no detailed travel surveys that can be

<sup>1</sup> As explained in the third section of this article.

relied on. There are no consistent planning authorities and methods. A gaming simulation would be required to model the planning methods and a further one (gaming-simulation) is required to develop data-proxies for the missing data.

**Outcomes of gaming simulations.** Depending on the objective of a given gaming simulation, its outcomes may vary from quantitative or qualitative data about the systems. The outcomes from the gaming simulations are used as input to traditional simulations and models or to validate the current models. The following is a sample of the list of objectives that will be used as input to generate the corresponding information for future analysis.

1. Capturing aspirations and service quality from transport infrastructure
2. Estimation of travel demand curve
3. Anticipating and Planning for spikes in travel demand
4. Modelling the social contexts for various stakeholders
5. Identifying the information required for each stakeholder for making decisions
6. Gaps in protocol, standards or institutional structure
7. Testing of transport plans with various levels of demands and output requirements

## Conclusions and Future Work

In this article we describe a new approach to identify and include people left out of traditional transport planning. We described an approach to use a new framework, the PSI framework for design and adopt traditional modelling tools around it. We plan to apply this methodology to the case of Randstad region of The Netherlands and the city of Bangalore, India to test its effectiveness in capturing different design contexts.

Our next steps is to apply the methodology and create parallel models for The Netherlands and India based on their respective contexts. Each location as different kinds of data at different levels of granularity. The PSI spaces for each location have to be modelled based on the gaming simulations that are currently in development.

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