

ABSTRACT

Transport infrastructure enables the transport of people and goods, providing services such as mobility, access and economic growth. To effectively provide these services to society requires effective planning. Planning the development of infrastructure has the aim to develop plans to change the function of infrastructure, e.g., adding a highway lane to increase capacity or providing charging stations for electric vehicles, to better meet the changing needs of society. These needs are better met, for example, if its users can travel further distances, in less time, more safely, emitting less, or with more reliability.

The added value of the infrastructure's change in function, i.e., the benefit of the infrastructure development, can only be experienced by society's many stakeholders (e.g., users) after the development project is complete. Once the projects have been approved and funded, they can be completed after being first tendered and then constructed. An approved and funded project is the product of the infrastructure planning process, which brings together multiple organisations and multiple stakeholders with diverging needs to agree on the planned infrastructure. Planning effectively can therefore take quite some time.

Often development projects are completed later than expected. Given that infrastructure development facilitates an improvement in accommodating societal needs once completed, their delayed completion can be argued to lead to societal costs, e.g., unnecessary delays on highways or incomplete charging coverage for electric vehicles, decelerating the shift from carbon fuels. The longer that infrastructure planning takes to result in projects that can effectively accommodate societal needs, the less efficient the planning process.

In most societies, transport infrastructure planning processes must be adhered to when developing infrastructure. The processes guide planners in eliciting the relevant societal needs and prepare the projects that can be approved and funded. Across administrative borders and different infrastructure types, the planning context can differ and accordingly the processes for the planning of infrastructure. This makes studying the infrastructure planning process challenging because of its heterogeneity. One way to generalise the task of transport infrastructure planners is to postulate the following: Transport infrastructure planners are guided by three questions throughout processes, so that the development projects effectively accommodate societal needs and are completed in a timely manner. These are:

1. How are societal transport needs likely to change over time?
2. How well could the current transport infrastructure accommodate the likely societal needs if no changes are made?
3. If it is likely that changes to the current transport infrastructure will be required, e.g., widening the highway to three lanes or building an additional railway line,

can the ideal modification be selected and approved within appropriate amounts of time with appropriate amounts of effort?

This work focuses on the third point, because there persists a gap to study the improvement of planning processes for infrastructure development. Based on a study of existing literature, the following can be summarised:

METRICS RELATED TO PROCESS IMPROVEMENT: Policymakers could benefit from methods that measure a change in planning processes (e.g., faster stakeholder engagement) and assess whether they create net value. This would be assessed relative to how quickly infrastructure planning processes can accommodate societal needs and the costs related to the process change. Such methods are scarce for infrastructure planning processes.

LACK OF PROCESS MAPPING: There is no publicly available literature detailing entire infrastructure planning processes, including inter-organisational dependencies and cross-sectoral coordination. Recent mapping and improvement efforts focus on single organisations or infrastructure types and studying process requiring more integration of organisations and infrastructure types remains unstudied. Moreover, corporate process improvement techniques fall short as they lack the capacity to address the political, social, and interdisciplinary complexities of transport infrastructure planning.

INADEQUATE TOOLS FOR EARLY-STAGE PLANNING: To answer strategic questions concerning land use and transport in early stages of planning, there is a need to be systematic and comprehensive in generation of variants. Infrastructure planners in early stages are challenged to model a large set of possible variants with a large set of possible futures in their studies to ensure a robust decision. Current predictive modelling tools are insufficient for early-stage planning under uncertainty due to data requirements and limited flexibility.

This thesis is focused on improving the efficiency of infrastructure planning processes. To assess whether an improvement has taken place, this work provides a way to measure efficiency-related process improvement proposals. Then, an infrastructure planning process is mapped and analysed to assess how well can it answer those three questions listed numerically above. Finally, a tool is proposed that can support infrastructure planners to scan regions for infrastructure development opportunities in early planning stages. The research conducted is therefore placed in the cross-section of infrastructure asset management, land use transport modelling, governance in planning and policy as well as project appraisal. To connect the research directly to practice, a case study in Canton Zürich was used as an example throughout the work.

Infrastructure development faces several challenges in decision-making. First, societal needs must be met while reconciling diverse stakeholder interests, e.g., travellers preferring faster travel versus residents avoiding noise emissions. Balancing these, and other stakeholder interests, requires the inclusion of different perspectives while planning and effective communication throughout the process, considering factors like the uncertainty related to the assumptions, available financial resources, required stakeholder

deliberations, and the availability of supporting planning tools. Second, multiple organisations are involved, each with distinct objectives and responsibilities, leading to coordination challenges, unintended consequences of infrastructure development and potential delays in infrastructure projects. Third, the lengthy planning duration spans years or decades, necessitating adjustments to the uncertain evolution of societal needs, which can complicate decision-making and affect the time that it takes to complete infrastructure and consequently, affect the time that societal value related to infrastructure development can materialise. Fourth, and last, the iterative nature of planning involves repeated proposals and revisions to accommodate changing conditions and stakeholder inputs. Here it must be kept in mind that stakeholder needs constantly change over time. While an extra iteration of the process may enhance the effectiveness of the planning outcome it can also prolong decision timelines and increase stakeholder costs. These challenges highlight the complexity of infrastructure decision-making, demanding careful management of stakeholders and processes to achieve the objectives of transport infrastructure development both effectively and efficiently. These challenges hold true for all planning contexts which aspire to involve local stakeholders through more decentralised decision-making. Other planning contexts may have highly centralised decision-making governance structures that enable very fast decision-making, e.g., for China's high speed rail network.

This work has resulted in contributions to the development planning of transport infrastructure systems under uncertainty as follows:

- A new concept of responsiveness for infrastructure planning processes offering a way to measure planning process improvement based on the trade off between the change in responsiveness of infrastructure planning processes and the change in societal value related to the planning process change. Responsiveness of infrastructure planning processes is defined for the first time in this paper as “the ability of infrastructure planning processes to accommodate societal needs quickly”. Improved responsiveness of planning processes alone does not necessarily lead to improved societal value; planning something in a rushed manner, may result in something less beneficial for society. Instead it must be ensure that the added responsiveness leads to improved societal value. To compare the costs related to making the process changes with the benefit of the reduced time needed for the planning process, the term ‘Value of Responsiveness’ is proposed. In essence, this allows for a trade-off of different costs and benefits related to a change in responsiveness, e.g., the inclusion of a streamlined environmental impact assessment and the change in societal costs and benefits related to change in time that the process takes. This is useful to address the issue that the time required for planning is currently not explicitly considered in decision appraisals. This assessment supports policymakers and their analysts to reflect on the value generated by each task in the planning process and assess whether and how changes in the process add value. This is important, because in Switzerland and many other places, politicians in the legislative branch are responsible for defining the process for an infrastructure planning process and are incentivised to make change that

adds societal value. This example shows how the value of changing a complex process can be communicated to different stakeholders.

- An assessment of the Swiss transport infrastructure planning process. First, an overview of the Swiss road and rail infrastructure planning process was created, for the first time, through the mapping of the process. This provides a thorough understanding of the basis upon which improvements are to be suggested. Second, the authors postulate what it requires to make a decision related to funding an infrastructure project using three decision-making criteria (technical readiness, societal consensus, and political-financial prioritisation). Then, the authors analyse the ability of planners to conduct planning so that it effectively and efficiently leads to decision-making related to financing infrastructure development. This is the first analysis of this kind conducted for infrastructure planning processes. Based on this, opportunities to address the challenges listed above are outlined. These opportunities were identified as: (1) A national organisation responsible for identifying ways that changing societal needs can be better accommodated in an integrated way. (2) A planning-support tool that would better estimate network-wide benefits of projects across all infrastructure types and consider multiple future scenarios. (3) All decision-support tools downstream of this initial planning task would consider future uncertainty to make development projects more robust to any future that could unfold. (4) A tool to support policymakers in critically reflecting on the added value of the planning task e.g., accelerating planning processes and reducing their duration, only where it is beneficial to do so.
- An assessment of Canton Zürich's cycling infrastructure planning process. A further contribution to the field of infrastructure planning process improvement, which was applied for the first time to cycling infrastructure. The paper includes mapping the existing cycling infrastructure planning process, identifying process-related challenges, and proposing targeted improvements. Key findings highlight the need for timely planning mandates, early-stage cost overviews, and systematic treatment of uncertainty to enhance planning process efficiency. It is argued that these process modifications can accelerate the realisation of cycling infrastructure projects to complete the cantonal cycling network plan, as expected by law by 2042. By bridging the gap between planning process design and infrastructure outcomes, this study shows that this example of analysing and improving planning processes is also useful for processes that are less institutionalised than road and rail infrastructure planning processes.
- A tool to improve the efficiency of infrastructure planning processes based on scenario planning for infrastructure development under land use uncertainty. Planning infrastructure in early stages is constrained by the available transport analysis tools. This tool generates many infrastructure variants and assesses them in many future scenarios, not feasible with existing tools. Through a transparent evaluation of the accommodation of societal needs, it addresses challenges such as stakeholder divergence and future uncertainty. The scenario-planning tool

studies a large set of interventions in a large set of possible future scenarios. The tool is suitable for early planning stages when uncertainty is at its highest, streamlines planning efforts, reduces iterative cycles, and fosters consensus among stakeholders.