Digital Twins for Augmenting Urban Planning

A Systematic Literature Review

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Introduction

Urban Digital Twins (UDTs) are often described as virtual replicas of real cities, digitally representing various physical, social, and economic assets, processes, and systems related to a city [1]. The increasing interest in UDTs is rooted in their potential for supporting urban planning & decision-making processes, management of operations, risk & resilience management, waste & resource management, as well as the provision of participatory mechanisms for civic engagement. However, UDTs can not be the general and single source of truth and should be customized for specificities of planning problems and context [2]. Therefore, a systematic understanding of the reciprocal relationship between UDTs and planning processes is necessary to realize the potential of UDTs.

Conceptual Framework

We conceptualize the FME framework for understanding and structuring this reciprocal relationship, by comparative analysis of prominent planning procedures [3]–[6] with methodological development and utilization of Spatial Decision Support Systems (SDSS) [7]–[9] and Planning Support Systems (PSS) [10], [11]. FME introduces 17 interdependent planning actions within three main phases of **Formulating**, **Modelling**, and **Exploring-Evaluating-Executing**; hence **FME**.

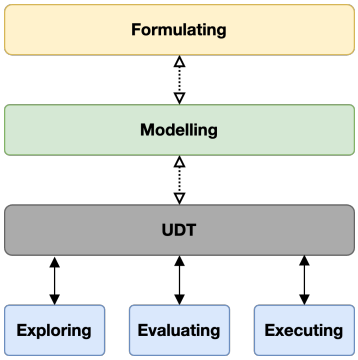

Figure 1: Interdependencies of planning phases in **FME** in relation with UDT.

Method

Through the lens of FME, we systematically review the literature (PRISMA [12]) to illustrate a comprehensive outline of the challenges and potentials of the development and utilization of UDTs. 182 records have been identified through database search, and 44 articles have been included in the review as they have discussed urban digital twinning for urban planning and decision-making purposes. For each article, we assess their contribution to each of the 17 planning actions in FME.

Review Results

Based on the depth and breadth of contributions to actions, we identified five types of articles: *Literature Review*, *Conceptual*, *Single-Method*, *Implementation*, and *Methodology*. Actions pertaining to data modelling [FS][MS], data integration [EO], simulation [EI], and visual interfaces [EV] have received contributions from more than half of the literature. On the other hand, actions pertaining to decision modelling [FD][MD], decision-making [MA][EA], and decision taking [EC] have received few contributions. This indicates that the majority of the literature still understands and implements digital shadows, rather than digital twins.

Moreover, we identified that developing and utilizing UDTs in planning processes faces challenges in the *evaluation* as well as ensuring *compatibility* with *external-physical*, *external-societal*, *external-digital*, and *internal-digital* systems. Finally, we maintain that UDTs are compound, contextual, and operationalized models. Therefore, understanding their functionalities can be based on the six possible permutations of the following sets: (prescriptive, descriptive) and (observation-based, simulation-based, hypothesis-based).

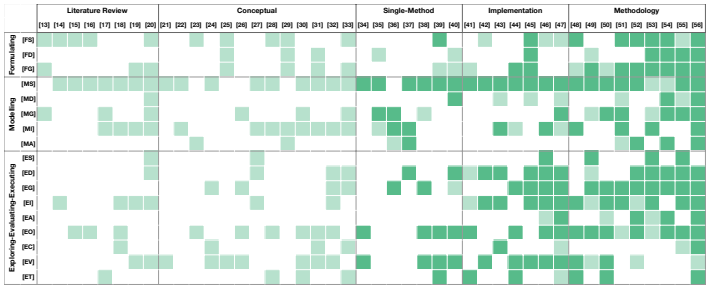

Figure 2: Heatmap of the contributions of literature grouped by type (columns) to planning actions in each phase (rows). Dark green: major contribution; Light green: minor contribution.

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References, reviewed literature, and digital version can be accessed through the QR code:

Built Environment Department - Urbanism and Urban Architecture

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