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jeopardised for good.

In addition, information requirements adopted from BIM-based standards and research provided foundations for city-level DT data requirements to build on. For example, according to ISO 19650 series, information requirements specify for what, when, how and for whom we should produce data used for facility and asset management during project commissioning (Sacks et al., 2020). Hence, (Sacks et al., 2020) combined BIM-based information requirements and technology, lean construction thinking, and AI to define the requirements for a holistic DT mode of design and construction. In this study, the key information components include Project Intent Information (PII), Project Status Information (PSI), and raw monitoring data etc. (Sacks et al., 2020), which can be further referenced and extended for city-level DT data requirements. (Cavka et al., 2017) developed the owner requirements for BIM-enabled facility and asset management including requirement categories, specific

is widely considered for stakeholder analysis within organisations and projects. For example, (Chung and Crawford, 2016) proposed using network-level, actor-level, and tie-level analysis based on the established social network for project management. (Lim et al., 2010) summarised stakeholder identification methods in categories of semistructured, checklist-based, interviews, and search, and figured out that the methods overlooked the bi-directional or single-directional links of stakeholders and the stakeholder prioritisation issues. Further, (Lim and Finkelstein, 2011) proposed a stakeholder identification approach based on social network analysis to specify and prioritise stakeholders and use it for eliciting functional requirements for large-scale software engineering projects. The abovementioned approach might be potential for city-level DT development in terms of stakeholder identification and data requirements establishment, while there is no existing study focusing on this area.

3 Research methodology

Figure 1 Methodology to develop data requirements for city-level DTs

3.1 Stakeholder identification phase

There are two phases in the proposed methodology (Figure 1). The first phase is to identify the stakeholder and establish the social network for city-level DT development, (Lim et al., 1999).

Literature review of the existing city-level DT studies is conducted to analyse the important stakeholders involved in

among them. Then, for the purpose to establish the network, clear definitions should be

output from sub-phase 1 is an initial stakeholder baseline model which is going to be used in sub-phase 2.

Then, sub-phase 2 is an iterative process with both empirical methods (i.e., semi-structured interviews) and data analysis, (Lim and Finkelstein, 2011).

during the DT development. The interviewees are found from two large-

Table 1 Identified stakeholders in existing city-level DT studies

City-level DT cases/research	Stakeholders/Roles	Reference
West Cambridge DT demonstrator for facility and asset management	university facility management team (facility manager (West Cambridge site), archive manager (West Cambridge site), technician (West Cambridge site), facility manager (the IfM building), technician (the IfM building)), academic team (team supervisor, researchers, technician), a consulting company (project director, technical support expert), modelling and data collection company (roles for collecting different data sources)	(Lu et al., 2020)
DT of the City of Zurich for Urban Planning	public administration, citizens, urban planners, designers, game users	(Schrotter and Hürzeler, 2020)

in Table 2 and Table 3. Based on the results, firstly, it indicates the project manager (provider side) in Project 1 has the highest degree, betweenness, and closeness centrality; and the

Figure 4 Preliminary findings for city-level DT development data requirements

5 Conclusion

Bringing city-level DTs from concept to practice, data management is a big challenge, where the organisational aspect of stakeholder involvement cannot be overlooked to ensure the successful development of the DT. This study firstly proposes the method including social network analysis to identify and involve stakeholders to establish data requirements that can instruct the data collection for city-level DT development and the DT application. The results of this study theoretically implies the important stakeholders and their relationships and how the the data requirements are driven by the stakeholders for the seek of city-level DT development; from the practical perspective, it can be used to guide the DT design and development more effectively. However, more details about the data requirements should be provided to prove the efficiency and effectiveness. In future work, stakeholder networks of more city-level DT projects in practice globally will be established and the data requirements will be further developed in terms of the named data needs in the preliminary findings.

Acknowledglofindings.

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