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Smart Cities' Strategies for Contractors: A Thematic Analysis of Selected Documents

Emad Najmi Sarooghi and Tamera McCuen, Ph.D.
University of Oklahoma
Norman, Oklahoma

This paper aims to identify the construction-related strategies in smart cities that could assist contractors in disrupting traditional construction processes using new technologies and processes. In this research, a thematic analysis was conducted to categorize the construction-related strategies in different themes by analyzing the smart cities' documents. The publicly available documents of 24 smart cities in the United States and around the globe, along with four international governments whose action plans will disrupt traditional construction processes, were analyzed. Based on the results, 29 action plans in six different themes were identified, including 1) Modern Infrastructure, 2) Livable Climate, 3) Efficient Mobility, 4) Education/Training, 5) Inclusive Economy, and 6) Affordable Housing. This paper shows that several smart cities have implemented some construction-related action plans, but other cities have no strategies related to the construction industry. The results of this paper could be helpful for further research to identify the future direction of construction in smart cities and define the knowledge and requirements needed for contractors to implement the action plans in smart cities.

Key Words: Construction Strategies, Smart Cities, Thematic Analysis

Introduction

In recent years, several technological advancements have changed traditional construction processes. Robotics application, the proliferation of electrical machines, the introduction of automatic mechanical tools, the introduction of new techniques in construction operations, and application of Artificial Intelligence (AI) and Building Informatics tools have disrupted traditional construction processes significantly in recent decades (Lekan, Aigbavboa, Babatunde, Olabosipo, & Christiana, 2020). Since the construction industry plays an imperative role in solving global warming and pollution of the planet by providing sustainable solutions, it is crucial to take advantage of new technologies to address these challenges through developing construction processes (Block, 2019). Also, disruptive technologies could help construction companies solve their productivity and performance problems (Love, Matthews, & Zhou, 2020). Woodhead, Stephenson, and Morrey (2018) tried to warn construction companies about the transformational process because of the introduction of technologies like the Internet of Things (IoT) and the need to adapt to this transformation.

The new advancements in technologies have changed construction processes in many ways. For instance, Vacanas, Themistocleous, Agapiou, and Hadjimitsis (2015) showed how using Building Information Modeling (BIM) in conjunction with Unmanned Aerial Vehicle (UAV) could change construction management processes through collecting accurate as-built data and demonstrating work progress for purposes like delay analysis and record keeping. Using BIM in construction companies even disrupted organizational settings like recruitment policies, and these organizations had to find new ways to manage this disruption (Ahmad, Hafeez, Ahmad, Aliyu, Rodriguez, & Dawood, 2016). Similarly, Ensafi, Thabet, Devito, and Lewis (2021) demonstrated how using Mixed Reality (MR) platforms such as HoloLive and Trimble Connect could improve the quality control process of as-built BIM models at project handover by verifying the model data and the quality of BIM graphics effectively regardless of the challenges these disruptive technologies could bring up. In 2016, Kothman and Faber studied the impact of 3D printing technology on the construction supply chain. Their findings showed that this new technology could facilitate the construction supply chain process by reducing logistical and production efforts. As another example of disruptive technologies, Labonnote, Ronnquist, Manum, and Ruther (2016) mentioned that additive manufacturing technologies have the potential to be used in the construction industry as a revolutionary solution. In addition, Fiske et al. (2018) investigated the potential of using additive construction to construct shelters for human crews on the Moon or Mars in the future. Moreover, robots can play an essential role in transforming construction processes. For example, four-legged robots can collect data more accurately and consistently and automate construction progress monitoring. These robots would reduce the time and effort needed for data collection in the construction workspaces (Afsari, Halder, Ensafi, DeVito, & Serdakowski, 2021).

Disruptive technologies need a proper place to be implemented, and the smart city is where that comes into play. This paper presents the construction-related strategies considered in smart cities' action plans. The purpose of this study was to provide an informational paper that shows construction-related strategies in different U.S. smart cities and other smart cities around the globe. There are different definitions of the smart city, but Dameri's 2013 comprehensive definition of smart city was used for this study. Dameri's definition states that "A smart city is a well-defined geographical area, in which high technologies such as Information and Communications Technology (ICT), logistics, energy production, and so on, cooperate to create benefits for citizens in terms of well-being, inclusion and participation, environmental quality, intelligent development; it is governed by a well-defined pool of subjects, able to state the rules and policy for the city government and development" (p. 2549). Based on this definition, high technologies would be a critical pillar of the smart city, and without them, it is not possible to create benefits for citizens. With this in mind, it is not surprising that smart cities around the globe are trying to incorporate these technologies into their strategic action plans. In this paper, the current construction-related strategies, which include disruptive technologies and processes, are explored to see how contractors can use them to disrupt traditional construction processes in the context of smart cities. Based on this, the research question is:

What strategies could be used by contractors to disrupt traditional construction processes in smart cities?

Methodology

The data used in this research was collected from public documents containing action plans for the economy, neighborhoods, health, education, mobility, environment, and modern infrastructure in smart cities. According to the Smart City Index 2021 reported by Smart City Observatory, 109 smart cities around the globe have been indexed. Also, based on Smart City Tracker Report 1Q18, a report from Navigant Research, there are 355 smart city projects in 221 cities worldwide, of which 55 cities are in the United States and Canada (Citron & Woods, 2018). Therefore, the research population for this study is comprised of the smart cities in these two reports. These two reports were published by the Smart City Observatory and Navigant Research and are considered the preeminent references used to index smart cities around the globe. Purposive sampling was conducted to select the documents for analysis. This type of sampling enables the researcher to focus on a particular portion of the population that has the best potential to answer the research questions (Rai & Thapa, 2015). Data for this research was collected from the publicly available documents of 24 smart cities and four international governments with action plans that will disrupt traditional construction processes (shown in Table 1). Of the 24 smart cities, 11 were in the United States, and 13 were from other countries around the globe.

Table 1

Research Sample

U.S. Cities	Number of documents	International Cities	Number of documents	Governmental documents	Number of documents
Austin, TX	1	Amsterdam	1	Australia	1
Boulder, CO	1	Canterbury-Bankstown	2	China	1
Cedar Rapids, IA	1			European-Parliament	1
Chula Vista, CA	1	Dubai	1		
Columbus, OH	1	Dublin	1	India	2
Dallas, TX	1	London	4		
Fresno, CA	1	North Sydney	1		
Henderson, NV	1	Seoul	1		
New York City, NY	4	Shanghai	1		
Philadelphia, PA	1	Singapore	1		
San Francisco, CA	2	Stockholm	2		
		Tel-Aviv	1		
		Tokyo	1		
		Toronto	1		
Total	15		18		5

Thematic analysis was used to analyze the action plans in each document. This method was chosen because it enables researchers to deal with complex data (i.e., texts in this research) and organize them using codes, categories, and themes (Peel, 2020). Thematic analysis is a common qualitative data analysis approach conducted in predefined steps. The first step in the analysis was a thorough review and identification of construction-related strategies. All construction-related strategies were highlighted in this step. Each highlight was then labeled and assigned codes to organize the highlights. These codes were determined using the main phrases in each highlight. Next, the related codes were assembled in categories based on themes. Then, the themes were reviewed to make sure there was no repetitive or outdated strategy. Finally, the themes were named and described

in detail based on the corresponding codes. Two researchers were used in the process of coding, organizing, and reviewing the themes to reduce the possibility of bias associated with the process of thematic analysis. The steps of thematic analysis used for this study are shown in Figure 1.

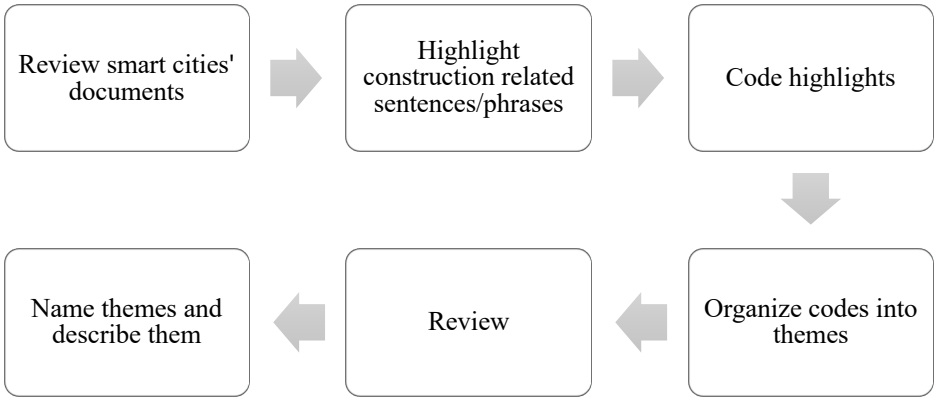

Figure1. The steps of thematic analysis used in this research

Results

A total of 38 documents with smart city-related strategies were reviewed. Of the 15 U.S. smart cities' documents, 18 construction-related strategies were identified from six smart cities, which included New York City, Cedar Rapids, Fresno, San Francisco, Boulder, and Chula Vista. The remaining five cities had no construction-related strategies in their documents. Similarly, of the 18 documents from international cities reviewed, only four cities, Seoul, Stockholm, Tel-Aviv, and London, had construction-related strategies. The remaining nine cities had no strategies related to the construction industry. Lastly, of the five government documents, only two of them contained strategies concerning construction industry challenges. These strategies were found in the Australian government document and the European Parliament document. Table 2 shows the number of strategies identified in each of the smart cities' documents. In the next step, the codes shown in Table 3 were used to label 36 highlights identified in smart cities' documents.

After labeling and coding the highlights, the related strategies were assembled to create the themes. In doing so, six themes were identified. During this step, seven strategies were eliminated after reviewing the themes and relevant strategies because they were repetitive, outdated, or identified as recommendations rather than action plans. Finally, the six themes were named and described as 1) Modern Infrastructure, 2) Livable Climate, 3) Efficient Mobility, 4) Education/Training, 5) Inclusive Economy, and 6) Affordable Housing. The themes with their description, related codes, and examples are shown in Table 4.

Table 2

Number of construction-related strategies identified in documents of smart cities and governmental documents

U.S. Cities	Number of strategies	International Cities	Number of strategies	Governmental documents	Number of strategies
Boulder, CO	2	London	10	Australia	1
Cedar Rapids, IA	1	Seoul	2	European-Parliament	1
Chula Vista, CA	1	Stockholm	1		
Fresno, CA	2	Tel-Aviv	3		
New York City, NY	11				
San Francisco, CA	1				
Total	18		16		2

Table 3

Codes used to label construction-related strategies

Codes	Abbreviation	Codes	Abbreviation
Zero carbon development	ZCD	3D visualizations of the city's infrastructure	3DV
Noise strategies	NS	Innovative construction methods	ICM
Cut emissions	CE	Using AI	AI
Dust control	DC	Urban delivery and Logistics	UDL
Green construction	GC	Delivery of construction related cargo	DCC
Project management	PM	Material delivery	MD
Improve cooperation with utilities	ICU	Construction skills training system	CSTS
Track city's projects	TCP	Online safety training	OST
Construction standards	CS	Apprenticeships	APT
Best practices in building construction	BPBC	Construction skills program	CSP
Geographic Information System	GIS	Human capital investment	HCI
Data sharing	DS	Affordable housing development	AHD

Table 4

Themes with their description, codes, number of construction-related strategies, and examples

Theme	Description	Codes	Number of strategies	Example
Modern Infrastructure	Includes strategies related to new technologies used for project management, data sharing, track city's projects and infrastructure, and innovative construction methods	PM, ICU, TCP, GIS, DS, 3DV, ICM	11	The Strategic Blueprint for Construction Excellence released by New York City Department of Design and Construction (DDC) including 10 strategies for project management
Livable Climate	Includes strategies related to cut emissions and dust control in construction processes, zero carbon development, waste management, and noise strategies	ZCD, NS, CE, DC, GC	9	Use of recycled materials made entirely of crushed construction waste in municipal construction and infrastructure works in Tel-Aviv
Efficient Mobility	Includes strategies related to delivery of construction materials in a smarter way at predefined times and locations	UDL, DCC, MD	3	Predefined loading and unloading access points using greater traffic data systems in San Francisco
Education/Training	Includes strategies related to construction skills training	CSTS, OST, APT, CSP	4	The Construction Skills program provides different trainings for New Yorkers to improve construction skills and increase career opportunities
Inclusive Economy	Includes strategies related to human capital investment to increase career opportunities for underrepresented groups	HCI	1	Connect more New Yorkers from underrepresented groups to construction jobs created by City investments
Affordable Housing	Includes strategies related to providing affordable housing to citizens in need using	AHD	1	Reduce time and cost in the development of affordable housing in NYC using Modular Construction

	innovative housing construction methods	
Total		29

Discussion and Conclusions

This paper conducted a thematic analysis to identify the construction-related strategies in smart cities' documents. Based on the results, 29 construction-related strategies were identified in smart cities in the United States and other countries around the globe. These strategies were categorized into six different themes, including Modern Infrastructure, Livable Climate, Efficient Mobility, Education/Training, Inclusive Economy, and Affordable Housing. The first theme is Modern Infrastructure, which consists of action plans related to disruptive technologies used for different purposes such as project management, data sharing between different entities, tracking city's projects and citizens engagement, and innovative construction methods like modular construction. The second theme, Livable Climate, includes action plans related to dust control, cutting emissions on construction sites, noise reduction, waste management on construction projects, and zero-carbon developments. Third is Efficient Mobility, which includes material delivery strategies with predefined times based on location in smart cities. Education/Training is the fourth theme, and it contains construction skills' programs or training systems in smart cities to increase career opportunities for citizens in the industry. Inclusive Economy is the fifth theme, and it is comprised of strategies focused on engaging underrepresented groups in the city's economy by providing career opportunities. The final theme identified is Affordable Housing, and it consists of action plans related to reducing the time and cost of constructing affordable housing by using new methods like modular construction.

To answer the research question, it is worth mentioning that construction-related strategies identified as six themes in this paper will assist contractors in using innovative processes and disruptive technologies in their projects in smart cities. This study shows that several smart cities have started considering specific construction-related strategies in their smart city action plans. However, many cities have no strategies related to the construction industry. Since contractors are important actors in smart cities, there is a need to implement more construction-related strategies. The findings of this study show that the contractors can use the modern infrastructure provided in smart cities for different purposes on their projects. These infrastructures include the Geographic Information System (GIS), 3D visualizations of the city's infrastructure, photo-realistic 3D models, standard project portfolio management software, and a smart city platform. For instance, the city's Geographic Information System (GIS) could be beneficial in the preconstruction phase for different analyses, such as flood hazard risk analysis and emergency response units' analysis (Najmi Sarooghi & McCuen, 2021). The 3D models of the city's infrastructure could help contractors locate utilities easier in their projects. The smart city platform enables contractors to share data related to project progress and even the photo-realistic 3D model of their project. Also, several strategies can improve the environmental aspects of the construction projects, such as using recycled materials in municipal construction and infrastructure works, green construction guidelines, and incentive programs. These programs enable contractors to cut emissions, control dust and noise on construction sites, and use lean construction principles to achieve zero carbon development targets. In addition, the strategies in the efficient mobility theme related to predefined loading and unloading zones and times could improve the material delivery to construction projects, while education/training programs could solve the labor shortage and increase career opportunities in this industry. Moreover, the human capital investment could provide more jobs for underrepresented groups to be involved in construction-related jobs and

solve the labor shortage in the industry. Lastly, using modular construction could assist contractors in developing affordable housing quicker in smart cities.

There were some limitations to this study. First, the researchers acknowledge that there may be other construction-related action plans and strategies in smart cities around the globe that were not included in the research sample. Secondly, adding more researchers for coding, organizing, and reviewing the themes could minimize the bias associated with the thematic analysis. Also, the necessity of doing more research to identify the future direction of the construction industry in smart cities and the required knowledge for contractors working in smart cities is undeniable. In addition, a similar study to assess the differences in construction-related strategies between U.S. smart cities and international smart cities is needed.

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