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The impact of policy instruments on the first generation of Tall Wood Buildings

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ABSTRACT

In a context of environmental concern and limited urban land, the construction industry faces the challenge of providing solutions for the increasing urban population both efficiently and sustainably. Numerous innovations on engineered wood products for multistorey buildings arise as one of the most promising solutions. In this context, various policies have facilitated the development of Tall Wood Buildings (TWBs). Yet, few publications analyse these policies and their influence on specific projects. This research aims to examine the impact of Policy Instruments (PIs) on individual TWBs qualitatively. Data collection is based on documentary review and semi-structured interviews with policymakers and professionals involved in 37 projects across eight countries. This study reveals that numerous TWBs have been facilitated by policies, acting through diverse PIs applied combined or in isolation. Notably, while Regulatory Instruments allowed TWBs in the first place, Research and Development Tools supported their development and approval process. Often, Research and Development Tools subsidised demonstration projects through Economic Instruments, after competitions or applications (Voluntary Policy Tools). Moreover, many Information Tools (e.g. campaigns, technical assessments) complemented other PIs. Remarkably, while some TWBs have become legal and technological precedents, technical information resulting from their development has influenced proposed changes in building codes.

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Introduction

By 2050, 7 out of 10 people will live in urban areas, an addition of 2.5 billion inhabitants (United Nations, 2018a). By 2030, cities will hold 5 billion inhabitants (United Nations, 2018b), and 3 billion will require new housing solutions. Based on these projections, housing demand will reach 300 million units (World Bank, 2016), 240 million of them in cities. In this context, high-rise buildings are projected as the primary affordable solution (Green & Karsh, 2012).

The increasing demand for urban high-rise housing units worldwide intersects with the urgent need to address climate change. The building sector can reduce 35% of greenhouse gas emissions and 50% of extracted materials in some regions (European Commission, 2011). Given that the most used materials – such as concrete and steel – can hardly store any carbon, buildings are potentially a long-term opportunity to reducing greenhouse emissions (Churkina et al., 2020). Developing engineering wood products for multistorey wood structures arise as a lower carbon and renewable alternative to steel and concrete (Ramage et al., 2017). During the growth of forests – through photosynthesis – trees absorb carbon dioxide from the atmosphere as they release oxygen into the atmosphere (Mayo, 2015). As a result, approximately 50% of the mass of a tree is carbon, which remains sequestered in wooden buildings' structure (Nakicenovic et al., 2000). Once timber buildings fall into disuse, wood can be reused or recycled into different wood-products (Churkina et al., 2020). If not, wood may be utilized as biomass, at which time the same amount of carbon previously absorbed by the tree is released into the atmosphere (Dammer et al., 2016). As part of the urban ecosystem, this carbon cycle can potentially last 500 years (Ramage et al., 2017).

The potential benefits are evident; yet, numerous social, economic, technical, and political issues pose difficulties for using wood in construction (e.g. Dumler et al., 2020; Vihemäki et al., 2019). Even when in developed regions, significant amounts of wood have been harvested without affecting forest resources negatively, across tropical and developing regions, inadequate forest-management practices resulted in substantial degradation and deforestation (Ramage et al., 2017). Additionally, the building sector has considerably less experience in wood construction than common materials, and thus, the respective products, processes and construction techniques are less developed

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(Riala & Ilola, 2014). Moreover, the regulatory contexts across countries limit multistorey wood construction development substantially (Dumler et al., 2020).

Given the multiple barriers multistorey wood construction must face, governments – mostly across Europe and North America – have implemented numerous policies for facilitating the development of tall timber structures. These policies include the easing of restrictions (Östman & Källsner, 2011), funds for research and development (e.g. Mohammad et al., 2018), information campaigns, certifications on environmental performance (e.g. Westerlund, 2012), and other wood-use policies. In this context, the construction industry has completed timber structures over 20 storeys, and proposals for higher buildings are under development (Green & Taggart, 2017). Additionally, concept designs have been proposed for structures up to 80 stories (Foster et al., 2018).[1]

However, there is a gap in the literature on the relationship between these policies and individual Tall Wood Buildings. Moreover, the literature has not analysed the mechanisms of action of policies – also named Policy Instruments. Based on documentary review and semi-structured interviews with policymakers and professionals involved in 37 projects across eight countries, this paper aims to examine how Policy Instruments have impacted the development of Tall Wood Buildings.

Background

Defining a Tall Wood Building

There is no consensus on how high a Tall Wood Building is, as it depends on many structural, shape, and material concerns (Foster et al., 2016). Foster et al. (2016) argue that a *tall building* can be any structure 'whose height is such that a fire cannot be fought from equipment based on the ground exterior to the building' (p. 2). The International Building Code (IBC) – valid in the U.S. and Canada – establishes this limit when a building has an occupied floor over 75 feet (i.e. 22.86 m) above the ground level at which fire department vehicles can access (ICC Council, 2006). In this context, the multistorey wooden buildings in North America – despite exceptional cases – have been limited historically to six storeys. European countries have defined limitations that vary across the continent but, like in North America, these restrictions generally do not exceed six storeys (Östman & Källsner, 2011). The arguments presented by Foster et al. (2016), the limitations established by the IBC, and the restrictions across Europe suggests that a *tall building* made from wood may be defined as any structure of at least seven stories – a definition adopted for this study.

Defining the materiality of any building is also debatable, as the parameters are not necessarily objective. However, the categories established by the Council for Tall Buildings and Urban Habitats (CTBUH) are frequently accepted by the academic community. According to the CTBUH (2019), buildings can be classified depending on the construction materials which conform the vertical/lateral elements and the floor spanning system. According to Foster et al. (2016), if timber prevails over other materials, the building should be considered a timber structure even when other secondary elements may be utilized to complement the structural system. These authors added that these could be a *single* material building if a unique material – steel, reinforced concrete, precast concrete or timber – conforms the structural system, a *composite* structure if it uses two or more materials combined in the structural system, and a *mixed* construction if two or more systems overlap (see Figure 1).

Policy instrument categories

A policy can be defined as a set of ideas, principles, or plans proposed or adopted by organizations or individuals. At a governmental level, the mechanisms for implementing these are called Policy Instruments (PIs). According to Howlett and Rayner (2007), these are 'techniques of governance which, one way or another, involve the utilization of state resources, or their conscious limitation, to achieve policy goals'. Vedung (1998) argued that PIs could be classified along the degree of coerciveness in terms of typologies: regulatory, economic, and information instruments could be arranged from more to less coercive, respectively. These typologies became a reference for environmental policy literature, maintaining a central position in studying policy instruments in the field (Pacheco-Vega, 2020).

The built environment has been shaped following guidelines and principles defined by PIs. Since the 1960s, these consider the impact of the construction sector on the environment (Van Bueren & De Jong, 2007). Since the early 1970s, governments have dealt with sustainability issues by implementing policies focused on regulations (Glasbergen, 1998). However, since the 1990s in industrialized countries, this paradigm changed and transformed public policies. First, from prescriptive to performance requirements; second, from

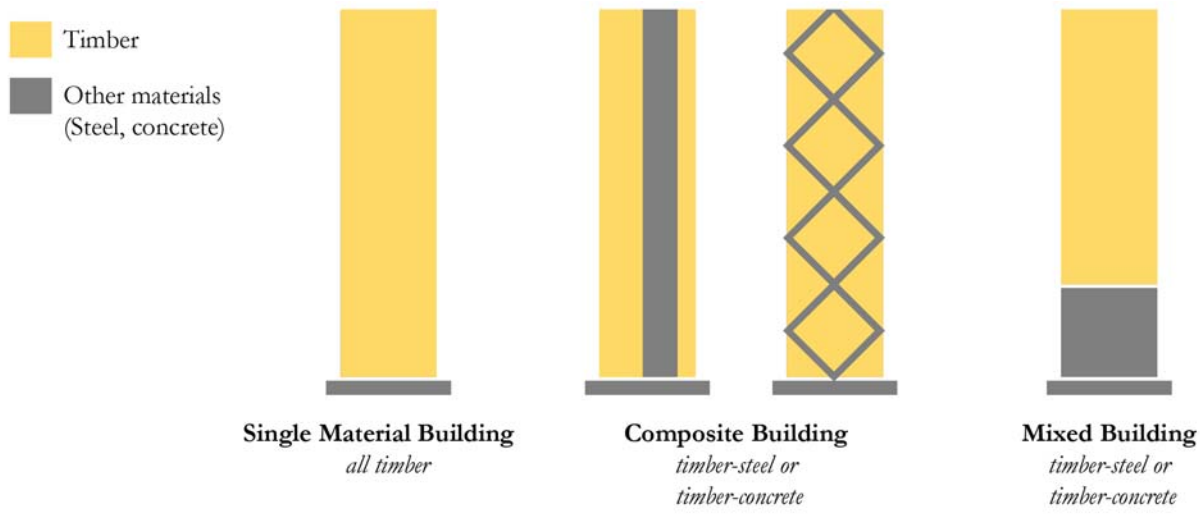

Figure 1. Building typologies in which timber prevails in proportion over other construction materials. Based on examples and figures in Foster et al. (2016).

regulation to market-based and voluntary arrangements; and third, from private initiatives to subsidiary research and development (Van Bueren & De Jong, 2007).

In this context, Kibert (2001) presented five categories of policy instrument for a sustainable built environment. This study considers Kibert's classification for analysing policies as follows:

(1) *Regulatory Instruments* (RI) are mandatory; therefore, they set an obligation to either using a technology-based or achieving a performance-based standard.
(2) *Economic Instruments* (EI) are financial incentives associated with the environmental impact of a particular activity.
(3) *Information Tools* (IT) aim to communicate relevant information regarding sustainability themes. They are subdivided into three sub-categories. First, *public information* campaigns raise public awareness of environmental issues. Second, *technological information* diffusion programmes provide technical information for producers aiming to change behaviour. And third, *environmental labelling* schemes offer information about the environmental performance of a product and its certification.
(4) *Voluntary Policy Tools* (VPT) can be unilateral when adopted by a business without public involvement, negotiated when they are the result of a public-private agreement, and selective when participation in governmental programmes is voluntary.
(5) *Research and Development Tools* (RDT) are based on a public–private partnership which compromises public funds to support R&D activities.

The policy framework on TWBs: from governmental regulatory barriers to promotion

Over the last decades, regulatory barriers that limit timber structures have been eliminated from building codes in Europe and North America. A study by Östman and Källsner (2011) identified that code edits in European countries had eased restrictions for multi-story timber structures by fire regulations – the most significant obstacle. In 1990, timber structures were limited up to two storeys by national prescriptive codes. In 2010, most European codes allowed timber structures over five storeys when compliance was demonstrated by performance. Similarly, in the US and Canada, the adoption of performance-based regulations opened the market for new building products, facilitating wood use in multi-storey projects. According to Goubran et al. (2019), the latter resulted in flexibilization of building regulations; and therefore, more experimentation and development. Yet, they added that these activities delayed projects and increased costs due to the demonstration processes. Concerning this, one study (FAO, 2020) indicates that these costs are uncertain; therefore, policies may have little impact on mitigating them.

Since 2008, the construction sector has completed more than 40 TWBs (Figure 2) over six storeys high in Europe, North America, and Australia (e.g. CTBUH, 2017; Harte, 2017; Smith et al., 2015; Zeitler Fletcher & De Jager, 2014). Following the

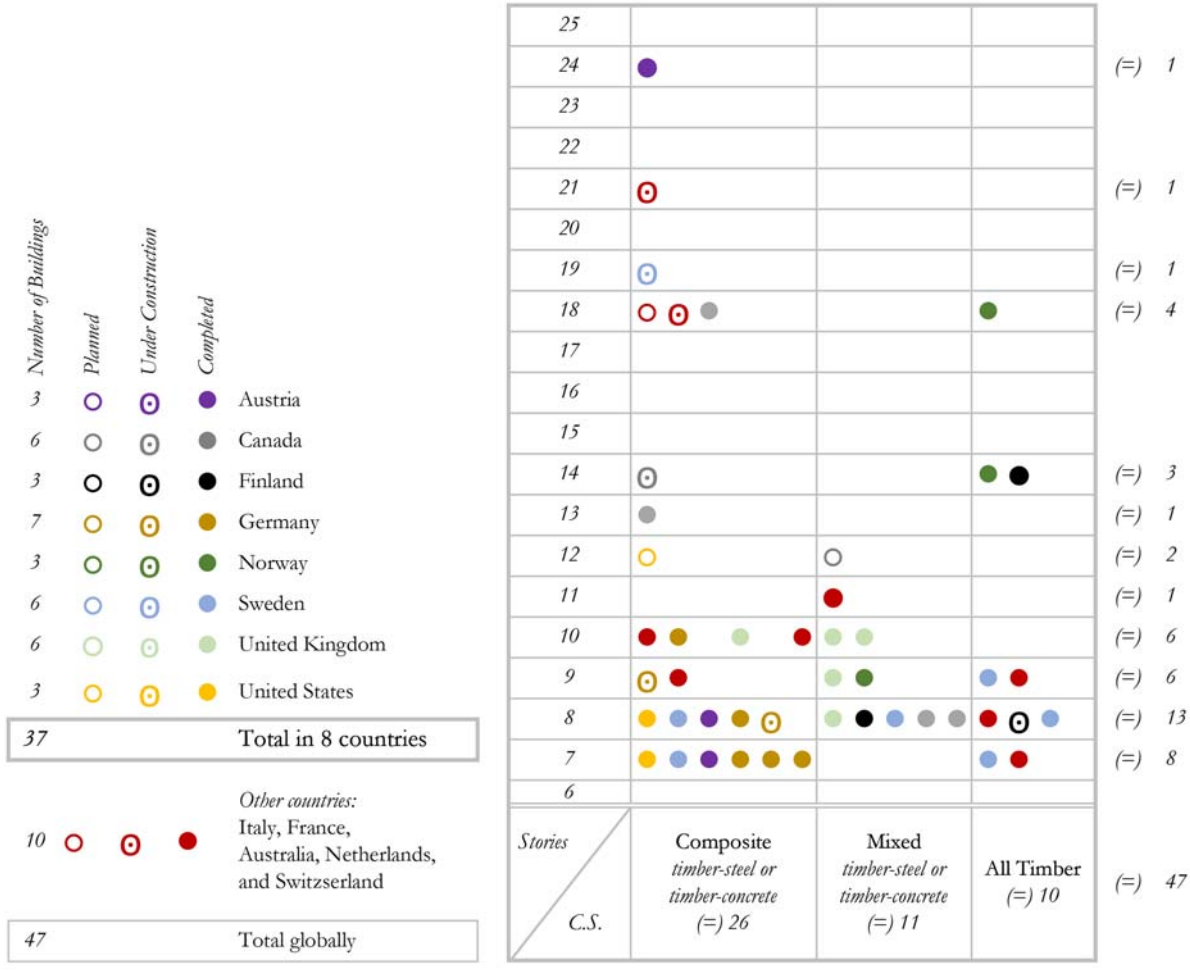

Figure 2. Distribution of TWBs over 6 stories since 2008, including projects completed, under construction and planned. Based on the data collected from surveys, academic articles, technical archives, and other documents.

development of TWBs, buildings codes in certain regions in Canada and the United States are being revised to provide prescriptive solutions for buildings up to 12 and 18 stories respectively (Breneman et al., 2019; Shelby, 2019).

Beside regulatory requirements, Vihemäki et al. (2019) suggest that economic and persuasive PIs may support wood construction – and these could be used in isolation or combined. Numerous policies based on diverse PIs were implemented to promote timber use by the building industry (e.g. Bowyer et al., 2016; Make it Wood, 2015; Milestone & Kremer, 2019; Oliver & Venables, 2012). Some of these PIs were directed to encourage TWBs. The latter resulted in new technologies available across marketplaces and a rapid increase in the number of buildings over ten storeys (Goodland, 2016).

In this context, policies have followed different approaches. For example – in Canada, France and Sweden – some policies have mandated the use of wood in buildings funded with public resources (e.g. Bremner, 2020; British Columbia, 2009; Westerlund, 2012). Other policies implemented by local governments in Sweden and Finland oblige timber-use in certain areas or sites (e.g. Westerlund, 2012; Wood Design and Buildings, 2020). Policies in Austria, Germany, Canada, Norway, and United States encouraged TWBs by funding research and development after voluntary competitions or applications. These grants often mandated the design of demonstration projects while supporting the design and authority's approval processes (e.g. Mohammad et al., 2018; Hein, 2014; Robinson et al. 2016). Interestingly, Vihemäki et al. (2019) highlight that effective innovation support requires appropriate regulations, information diffusion and private interest. Finally, policies focused on information campaigns on timber construction benefits were implemented in countries such as, Sweden, Norway, and United Kingdom (e.g. Bowyer et al., 2016; Røtnes et al., 2017; Westerlund, 2012). One study (FAO, 2020) suggests that campaigns may increase the number of TWBs completed.

Overall, the literature has examined policies for promoting wood construction; however, few publications discuss policies directed to facilitate the development of TWBs exclusively. Moreover, PIs have not been analysed, neither their impact on TWBs.

Research design

To gain insight into the impact of PIs on the developments of TWBs, 37 TWBs were studied in detail, analysing qualitatively the specific policies and PIs that influenced their development.

Survey methodology

This study compiled a database of 47 TWBs developed since 2008 globally (e.g. CTBUH, 2017; Harte, 2017; Smith et al., 2015; Zeitler Fletcher & De Jager, 2014). However, a selection of buildings was included in this study according to the following criteria (see Figure 3):

- TWBs over six stories which can be classified under any of the three categories defined by Foster et al. (2016): mixed, composite, or all-timber buildings.
- TWBs planned (with building approval), under construction or built.

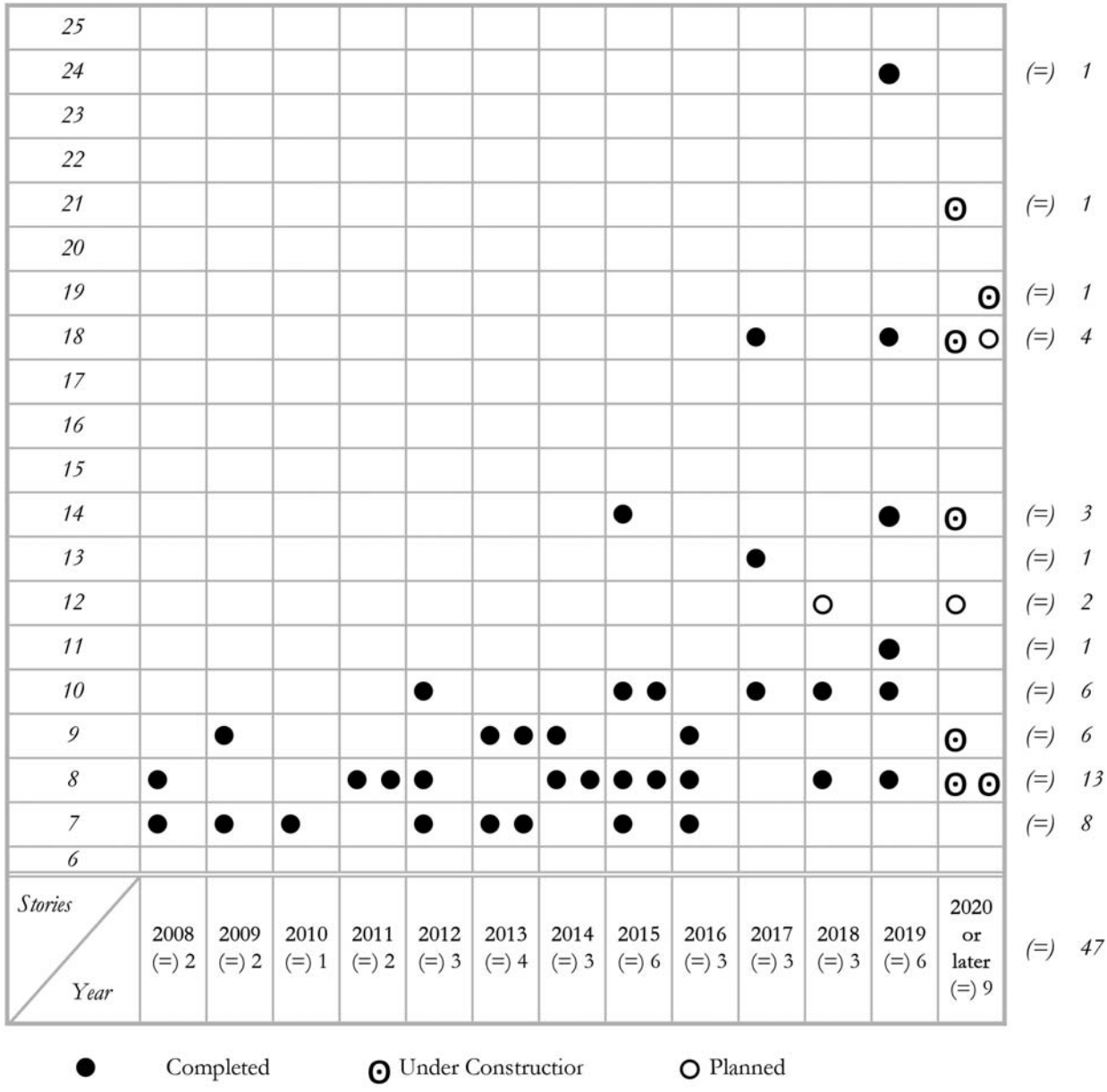

Figure 3. Distribution of TWBs over 6 stories across the timber-based construction systems categories defined by Foster et al. (2016). Based on the data collected from surveys, academic articles, technical archives, and other documents.

- TWBs located in countries with at least three TWBs. It was expected that in countries with less projects, more time is needed for policies to achieve outcomes.

This sampling criteria resulted in 37 TWBs located in 8 countries.

Data collection

Selected TWBs were studied to understand how policies impacted on their development. An exhaustive survey of the existing TWBs was conducted using a range of documentary sources available. Existing data on the TWBs and related-policies was collected from multiple sources including: (1) government reports, construction, and urban planning laws published since the early 2000s, which were accessed online; (2) public reports of developers and architecture firms, such as technical reports and press releases; (3) academic publications, policy reports and surveys; and (4) news and media articles of TWBs and policy programmes.

Novel data was obtained through semi-structured interviews with key actors. Interviewees were solicited by email after being traced through internet searches. Prospective interviewees were identified by these professionals who provided names of other key stakeholders. As a result, further professionals were contacted due to their in-depth involvement in the projects. Also, a number of policymakers were contacted after professionals highlighted the impact of specific policies on the development of selected TWBs. Interviews were conducted by email, telephone, and video conference. The response success rate of the interviews was 60% in five months.

A total of 33 interviews were conducted with professionals and policymakers from various backgrounds and countries (Table 1). The interviews followed a semi-structured questionnaire, designed to cover general questions focused on understanding what and how policies facilitated the development of projects. On the one hand, some questions were designed to be specific enough to obtain the name of specific policies (when interviewing professionals) or buildings (when interviewing policymakers). On the other hand, other questions – mostly about qualitative specificities of policies and TWBs – where sufficiently open for not directing the interviewee in a particular direction.

Table 1. Data collection Interviewees background and overview.

Interviewee background	Non-government	Government
Policymaker / Policy advisor (involved in policies reviewed)		(1 AUT, 2 CAN, 2 NOR, 1 UK, 1 US)
Architecture	1 AUT, 2 CAN, 2 FIN, 1 GER, 2 NOR, 1 SWE, 1 UK, 1 US	
Client / Developer	1 AUT, 1 CAN, 1 FIN, 1 SWE	
Engineering	1 GER, 1 NOR, 2 CAN	
Construction Company / Timber Supplier	1 NOR, 1 FIN, 2 SWE, 2 CAN	
Total	26	7

Notes: AUT = Austria; CAN = Canada; FIN = Finland; GER = Germany; NOR = Norway; SWE = Sweden; UK = United Kingdom; US = United States.

Data analysis

For understanding the impact of PIs on TWBs, the data collected was analysed following two different approaches:

(1) Analysis of policies within national frameworks based on document examination and interview responses. Each policy is classified according to Kibert's (2001) criteria.[2] Description and categorization are presented in a table for each country (Table 2). Each policy is categorized depending on the administrative level of implementation (e.g. national, municipal, provincial). Complementarily, the text examines how each policy facilitated the development of TWBs selected. This relationship is qualitatively examined and supported by literature and interview references. Throughout the text, interviewees are identified as *policymaker(s)* when having a government affiliation. Non-government interviewees are identified generically as *professional(s)* to maintain their anonymity.
(2) Based on each policy's impact and categorization presented in country-specific analysis, this article then analyses the relationship between PIs and

Table 2. Policies, administrative level of implementation, policy description and categorization according to Kibert's (2001) criteria Data analysis.

			Policy instruments				
Policy (or institution)	Administrative level	Description/aim	RI	EI	IT	VPT	RDT
Name of Policy 1	(Regional, national, municipal, etc.)	Description of Policy 1	●		●		
Name of Policy 2	(Regional, national, municipal, etc.)	Description of Policy 2				●	●
Name of Policy 'n'	(Regional, national, municipal, etc.)	Description of Policy 'n'	●				●

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

TWBs across countries, focusing on the qualitative aspects of PIs. A table with all TWBs selected describes how specific PIs impacted on their development (Table 3). The text complements the table, examining similarities and differences across projects and countries. This analysis sets the guidelines for the discussion, and conclusions of this research.

The local policy contexts

Austria: performance-based code for innovative projects

Austria was a pioneer of *performance-based code* adoption worldwide (Meacham, 2009). This alternative path made it possible to use innovative solutions but required demonstrating code compliance. One policymaker exemplified this indicating that 'according to the Austrian fire regulations, timber construction in high-rise buildings with more than six stories needs additional compensation measures'. Despite additional requirements, three TWBs included in this study have been developed in Austria; Life Cycle Tower One (in 2008), Wagrammer Strasse (in 2013), and HoHo (in 2020) with 8, 7, and 24 stories respectively.

One policymaker highlighted that the national programme *Building of Tomorrow* facilitated the development of Life Cycle Tower One (Table 4). The initiative supported the cross-professional research project named *eightpluss*. This collaboration – which also involved academia – resulted in developing both an innovative building system, and the 8-storey prototype (Mayo, 2015). The team conducted fire and acoustic tests for achieving code compliance, and constructability tests to improve assembly processes and reduce construction costs (Hein, 2014).

In 2009, Vienna launched the competition Timber Construction in the City aiming to promote wood-based residential apartments. This initiative subsidized the 7-storey Wagrammer Strasse, completed in 2013 (Schluder Architektur, 2013). Stakeholders involved developed various building solutions, for achieving acoustic fire and, structural performance values required (Binderholz, n.d.).

Performance-based criteria were also the required path for completing the 24-storey Hoho in Vienna in 2020. One professional indicated that the project obtained exceptional approval after extensive testing and consultation with authorities – a process financed exclusively with private resources. The team – assisted by an academic institution – conducted acoustic and fire tests for achieving code compliance. The project was built according to the criteria *Total Quality Building Assessment,* an independent certification developed by the Austrian Sustainable Building Council (ÖGNB), which documented various technical and environmental voluntary and mandatory parameters (Geissler & Bruck, 2012.). Concerning this, one interview highlighted:

Table 3. Data analysis Impact of policy instruments on TWBs.

Building (country and year)	Policy instruments				
	Regulatory instruments	Economic instruments	Information tools	Voluntary policy tools	Research and development tools
Building 1 (Country, year)	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.
Building 2 (Country, year)	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.
Building 'n' (Country, year)	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.	Qualitative description of impact.

Table 4. Categorization and description of policies implemented in Austria.

Policy (or institution)	Level	Description/aim	Policy instruments				
			RI	EI	IT	VPT	RDT
Performance-based code	National	Alternative path to obtaining building approval when performance required is demonstrated.	●				
Building of Tomorrow (Haus der Zukunft)	National	Research and technology program designed to supporting evironmentally friendly and renewable materials in construction.		●		●	●
Timber construction in the city (Holzbau in der Stadt)	Municipal	Competition launched by the city of Viena which aimed subsidize apartments made out from wood.		●		●	
Total Quality Building Assessment System	Independent	Tool for assessment and certification of technical and environmental criteria (includes voluntary and mandatory parameters).	●		●	●	

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools;

> [T]he special requirements in terms of structure planning, fire protection and efficient usability are particularly critical. The construction system kept deliberately simple, combines systems already available on the market […] each material is used in a manner, ensuring that the various requirements are best met.

Canada: competitions as key drivers

The National Building Code of Canada limits the height of wooden structures up to 6 storeys, or 18 meters.[3] However, higher buildings can be developed under a *Site-Specific Regulation*. This regulation requires to demonstrate compliance by performance criteria (University of British Columbia, 2016). Remarkably, all TWBs in Canada have obtained construction approval through this path.

In Canada, British Columbia has been a pioneer province in promoting timber construction, since implementing the *Wood First Act* in 2009 (Table 5). This policy mandated the use of wood in provincially funded buildings (British Columbia, 2009). In this context, the University of British Columbia (UBC) developed the first TWB in the country – Wood Innovation and Design Center in 2014. This 8-storey structure exceeded the height limit prescribed by the building code at the time, requiring the project to demonstrate fire safety and acoustic performance values (Woodworks, 2018).

Also in British Columbia, the 18-storey Brock Commons was developed as a result of the competition *Tall Wood Building Demonstration Initiative (TWBDI)* – a policy based on multiple instruments. One professional involved in this project highlighted TWBDI as crucial for funding tests to achieving code-compliance and improve construction efficiency. Additionally, another professional indicated that the grant provided technical assistance for this process.

A policymaker explained this further:

> [T]he government of Canada short-listed this demonstration project and another one in eastern Canada [Origine] for funding incremental eligible activities including R&D (fire, structural and acoustic testing, etc.). Intent of this program was to encourage the commercial and regulatory uptake of tall wood buildings in Canada by supporting demonstration projects.

In Quebec, TWBDI selected the 13-storey Origine, which also received funding from the *Ministry of Forests, Wildlife and Parks*. According to one professional, both funds enabled beneficiaries to conduct the required R&D activities to demonstrating fire safety and acoustic values required. Based on these results, the *Régie du bâtiment du Québec* published the *RBQ Guide*, the primary guideline to complete TWBs in the region. One professional explained how the following project – the 8-storey Arbora – benefited directly from these guidelines and demonstrated the economic viability of TWBs when legal precedents are available:

> The level of demonstration required for the Arbora project was considerably lower than for the Origine project. On the basis of the studies carried out for the Origine project and the guide published by the RBQ, only a few proposals for alternative solutions have been necessary.

Following the TWBDI, the Canadian government launched the *Green Construction Wood Program*. According to one policymaker, this programme sought to influence building code editions and promote advanced educational activities. However, he argued

Table 5. Categorization and description of policies implemented in Canada.

Policy (or institution)	Level	Description/aim	Policy instruments				
			RI	EI	IT	VPT	RDT
Site-Specific Regulation (Performance-based code)	Provincial	Alternative path to obtaining building approval when performance required is demonstrated.	●				
British Columbia Wood First Act	Provincial	Promotion of wood. Wood-use requirement for specific cases. Assistance and recommendations. Development of regulations.	●		●		
Tall Wood Building Demonstration Initiative (TWBDI)	National	Competition for support of demonstration projects Funds for incremental activities of demonstration TWBs leading to building permit. Assessment of technical issues. Also, communication, training and education.		●	●	●	●
Ministry of Forests, Wildlife and Parks (Ministère des Forêts, de la Faune et des Parcs)	Provincial	Support to developing R&D activities of demonstration projects.		●			●
RBQ (Régie du bâtiment du Québec) Guide	Provincial	Publication of construction solutions for buildings up to 12 stories.	●		●		
Green Construcción Wood Program (GC Wood)	National	Funds for advanced education activities and R&D associated with selected demonstration projects. Promotion of wood in construction. Funds to supporting technical information for revision of the building code.		●	●	●	●
Ontario Mass Timber Program	Provincial	Funds for R&D activities of selected projects (i.e. building approval and technical issues). Technical training.		●	●	●	●

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

that GC Wood also aimed to continue supporting TWBs similarly to TWBDI.

GC Wood endorsed two TWBs. First, the 14-storey University of Toronto Building – also supported by the *Tall Demonstration Project of Ontario's Mass Timber Program* – received economic and technical support for project development and code compliance. According to one professional involved, this assistance included testing, research, peer-review, and extensive consultation. Second, the 12-storey Arbour in Toronto, in addition to GC Wood, received a complementary grant from the provincial government. One professional indicated that these resources financed extra service fees to producing detailed alternative compliance reports on fire and structural issues. These funds also supported additional constructability tests and tours to fabrication plants to assisting informed decisions:

> [T]he principle around the funding is to pay for any costs (soft costs, not the building itself) over and above what it would cost to do the building out of concrete or steel.

Finally, it is worth highlighting that two policymakers indicated that some of these policies and TWBs influenced code editions in Canada and the US to allow wood buildings up to 12 and 18 stories, respectively.

Finland: achieving fire safety for completing projects

In Finland, the 2011 edition of the *Building Fire Code* eliminated restrictions for timber residential and office multistorey buildings (Franzini et al., 2018; Karjalainen, 2015). Since then, three TWBs have been completed in Finland; Wood City, Puukuokka, and Lighthouse – with 7, 8 and 14 stories. One professional involved in Puukuokka highlighted the relevance of this code edition:

> [The code edition] gave us the impetus for exploring the possibility of creating a wooden apartment building of multiple stories with an architectural expression of its own. This is how we got started in thinking about the Puukuokka project.

Another professional involved in Wood City explained:

> It would have been impossible to build 8 stories high wooden building before 2011.

Even when this regulatory barrier was eased, TWBs may be required to demonstrate code compliance according to the *Performance-based Code* (Table 6). For example, Puukuokka required the involvement of a fire protection engineer (Green & Taggart, 2017). Similarly, one professional indicated that Lighthouse needed no fire tests, but a simulation of fire performance. Additionally, authorities required structural inspections (Puu, 2018).

Along with the regulatory framework, other policies facilitated the development of these projects. *The National Wood Construction Program* aimed to increase the market share of multistorey timber buildings, supporting projects, research programmes, and educational activities. This initiative encouraged cooperation between actors in the field (Karjalainen, 2015). In this context, one professional indicated that Puukuokka-initiated by the City of Jyväskylä – was conceived as a collaboration with the design team and industry actors. Wood City also resulted from a collaboration – a *competition* in which the City of Helsinki and other private actors and organizations were appointed as juries (City of Helsinki, 2020). Likewise, the *City of Joensuu* – supported by the Ministry of Environment – was actively involved in Lighthouse project. According to one professional, the city subsidized the project, revealing a political decision for demonstrating the potential of wood in construction. Moreover, the city's *zoning plan* specified the construction of a TWB in the site (Wood Design and Buildings, 2020).

Germany: following technological precedents

In Germany, the edition of the Model Building Code (MBC) in 2002 increased the permitted height for timber structures from three to five storeys – or 13 meters – under prescriptive requirements (Mahapatra et al., 2012). Later, due to the adoption of a *performance-*

Table 6. Categorization and description of policies implemented in Finland.

Policy (or institution)	Level	Description/aim	Policy Instruments				
			RI	EI	IT	VPT	RDT
Building Fire Code Edition	National	Fire code edition allowed wood buildings up to 8 stories.	●				
Performance-based code	National	Alternative path to obtaining building approval when performance required is demonstrated.	●				
National Wood Construction Programme	National	Reducing carbon emissions by increasing the use of wood in construction. Supporting projects, education and R&D activities related to wood construction. Facilitating cooperation amongst actors in the field.		●	●	●	●
Wood City Competition	Municipal	Architectural competition				●	
City of Joensuu	Municipal	Economic support of demonstration project. Demonstrating wood construction potential. Planning considers wood-use in a specific site of the city.	●	●	●		

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

based code, it became possible to build higher timber buildings if fire safety code compliance is demonstrated (Östman & Källsner, 2011) (Table 7). In this context, in 2008, the construction of E3 – a seven-story timber building – became a novelty in Germany and Europe (Moore, 2016). The approval process required the team to conduct feasibility research, tests, components certification, and discussions with authorities. Based on the E3 as a precedent – and with less resource-consuming regulatory barriers – the same architecture office designed and completed two projects: the C13 in 2014 with seven storeys (Mayo, 2015) and SKAIO with ten storeys in 2019.

In Bad Aibling, the *German Environmental Foundation* supported a collaboration between Shankula Architects, the developer B&O, and academic researchers to developing the 8-storey H8 building in 2011. This programme funded fire tests required to gaining building permission following authorities' suggestions. H8 followed a 4-storey pilot developed previously for testing various other technical principles (Mayo, 2015).

The Austrian policy *Building for Tomorrow* also explains the construction of three TWBs in Germany. This programme supported the R&D activities to develop a composite building system called Life Cycle Tower One. Based on the results, the 7-storey H7 was completed in 2014 in Berlin (Hein, 2014). H7 achieved code compliance of fire safety, acoustic and structural requirements with simple means (Hein, n.d.). According to one professional, the composite-nature has advantages because 'the system is more code-friendly than all-wood structures'. This professional added that the SXB towers (2021) – with seven and eight storeys respectively – follow the same principles.

Norway: synergy of multiple policy instruments

Multistorey timber buildings are not pre-accepted in Norway as developers need to demonstrate compliance with performance criteria (Goodland, 2016). Yet, various professionals indicated that it is particularly challenging to comply with the fire safety requirements established in the *performance-based code*. In this context, the government organization Innovation Norway launched the initiative *Wood Innovation Programme*, aiming to encourage the creation of value across the wood industry (Table 8). This programme implemented a policy called *Tree in the City* (*Tre I by*), which financially supported the approval process of selected projects, such as the 14-storey Treet in 2015 (Røtnes et al., 2017). One professional involved in Treet indicated that it was required to provide complete documentation of new technical solutions, including fire safety performance values, a process also supported by the *Norwegian Research Council.* Another professional indicated that the team conducted constructability and structural tests with the assistance of a research institute.

Tree in the City also funded a feasibility study to convince the municipality to grant the *building permit* under special considerations (Røtnes et al., 2017). One professional explained:

> [T]he regulation was modified to allow two more stories. This was done to maximise the potential of the construction principle […] In this process, the local municipality and planning authority made sure to include an article that ensured the use of wood as main material in the building.

The 18-story Mjøstårnet (in 2019) was also required to demonstrate performance criteria. However, one professional indicated that in this case only limited funding from Innovation Norway was granted, as most of the R&D activities were funded privately. The company conducted large-scale tests to improving the assembly process. Additionally, one professional highlighted that the fire requirements were complicated to demonstrate:

> The Mjøstårnet building had to meet the demand of a burnout scenario without collapsing. This was challenging, and led to a series of fire tests to convince authorities that the building will still stand after a fire cell is completely burned out.

Lastly, *Wood Innovation Programme* also supported Moholt – a 9-story all-timber building finished in 2016. The grant financed structural tests, contractors' training, and fire tests (Lien and Lolli, 2019). One professional remarked that a real-scale unit was burned to

Table 7. Categorization and description of policies implemented in Germany.

Policy (or institution)	Level	Description/aim	Policy instruments				
			RI	EI	IT	VPT	RDT
Performance-based code	National	Alternative path to obtaining building approval when performance required is demonstrated.	●				
German Environmental Foundation	National	Economic support for R&D activities and the construction of demonstrative TWB.		●		●	●
Building of Tomorrow (Haus der Zukunft)	National (Austria)	Research and technology program designed to supporting environmentally friendly and renewable materials in construction.		●		●	●

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

Table 8. Categorization and description of policies implemented in Norway.

Policy (or institution)	Administrative level	Description/aim	Policy instruments				
			RI	EI	IT	VPT	RDT
Performance-based code	National	Alternative path to obtaining building approval when performance required is demonstrated.	●				
Wood Innovation Programme (Trebasert Innovasjonsprogram)	National	Program to encouraging wood-use for creating value in the woodworking industry, through funding of R&D activities. Information campaigns and technical assistance.		●	●	●	●
Norwegian Research Council	National	Promotion and support of R&D activities in the industry sector.		●		●	●
Zoning Planning (Bergen)	Municipal	Building permit exemption. Wood-use in specific building.	●				
Enova	National	Funding to promoting energy-efficiency design practices.		●		●	●
Cities of the Future (Framtidens byer)	National	Support of pilot climate-friendly projects, such as wooden buildings.			●		

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

demonstrating fire safety. This professional also explained that a grant from *Enova* encouraged timber-use as a measure to improve energy efficiency. Another professional highlighted that this project was promoted by the governmental initiative *Fremtidens byer*. This programme promotes sustainable development projects in 13 Norwegian cities, divulging information about exemplary wooden buildings.

Sweden: city's initiatives as key promotors of buildings.

Since 1994 multistorey timber buildings are not prohibited in Sweden. Yet, *performance-based requirements* have to be met according to the Bokerke's Building Regulation (Landel, 2018). Even when this process may increase overall expenses, six TWBs completed in Sweden followed this alternative path: Limnologen, Portvanken, Vallen, Älvsbacka Park, Kulturhus and Strandparken. One professional involved in the 8-storey Strandparken (completed in 2015 in Sundyberg) indicated that additional costs for activities required to achieving code compliance were explicitly negotiated between the stakeholders involved. Another professional explained this further:

> We made fire, acoustic and preassembly [tests]. All of it was done together with our manufacturer that was collaborating with the Universitys in Luleå.

In this context, several policies have been implemented across the country to facilitating the development of TWBs (Table 9). Since 2004, the *Swedish National Timber Construction Strategy-SNTCS* aimed to increase the use of timber, extending wood research and development operations, and supporting diverse public and private collaborations (Ollonqvist, 2011). The SNTCS incentivized Växjö city to implement the programme *More timber in construction.* This policy aimed that wood should be considered as an alternative for new projects and multi-story buildings (Westerlund, 2012). Moreover, the initiative provided funding for R&D activities associated with timber construction (Växjö, 2005). In Välle Broar district in Växjö, this strategy states that timber should be used in one to two projects yearly for ten to 15 years (Westerlund, 2012).

In this context, Växjö City collaborated with industry and academia to create a research centre directly linked with the 8-storey Limnologen – the first TWB completed in 2008 (Westerlund, 2012). This building – also an initiative project of the SNTCS – gained

Table 9. Categorization and description of policies implemented in Sweden.

Policy (or institution)	Level	Description/aim	Policy instruments				
			RI	EI	IT	VPT	RDT
Performance-based code	National	Alternative path to obtaining building approval when performance required is demonstrated.	●				
Swedish National Timber Construction Strategy	National	Promotion of timber in construction. Support of R&D collaborations between private and public actors.			●	●	●
More timber in construction (Mer trä i byggandet)	Municipal	Mandatory consideration of timber for new buildings. Support of specific timber projects. Funding for R&D activities. Also, incentives for cooperation amongst stakeholders.	●	●	●		●
Swedish Energy Agency & Vinnova	National	Support of passive energy strategies of demonstration projects.		●		●	●
Sustainable Skellefteå (Hållbara Skellefteå)	Municipal	Promotion of sustainable construction, focusing on the entire life service of buildings.			●	●	
Green Building (Miljöbyggnad)	Independent	Labelling scheme. Certification of the environmental impact of projects, such as building materials.			●	●	
Skellefteå City Competition	Municipal	Competition to developing a public building with sustainable attributes.		●		●	
Trastad	National	Diffusion of exemplary wood buildings.			●		

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

construction permit after demonstrating fire safety through analytical design – amongst other structural and acoustic requirements (Landel, 2018). Also in Växjö, the *Swedish Energy Agency and Vinnova* supported the design of energy efficiency measures of Portvatken (two eight-storey towers completed in 2010) as part of the Agency's demonstration projects program (Johansson & Schauerte, 2015). Finally, in Välle Broar, the 8-storey Vallen was completed in 2014. Portvakten and Vallen projects required to demonstrate fire safety and acoustic performance values (Landel, 2018).

Unlike the Växjö approach, in Skellefteå, there is no timber construction plan, but a strategy for sustainable construction called *Sustainable Skellefteå*. This strategy focuses on promoting the reduction of the environmental impact of construction materials over their entire service life and promotes exemplary cases (Westerlund, 2012). Since its implementation, three seven-storey timber towers named Älvsbacka Park were completed between 2008 and 2010 (Skellefteå Municipality, n.d.). This project was assessed by the Swedish environmental classification system *Green Building*. This tool evaluates the building as a whole and considers building materials and their respective environmental impact (Westerlund, 2012). Finally, Skellefteå Municipality launched a *competition* to developing the 19-storey Kulturhus. According to one professional involved, the municipality has been actively promoting the use of timber in construction – a joint venture with the industry and academia:

> A public architecture competition announced in 2015 led to our participation […] The task was to design a public building with a high sustainable profile.

It is worth highlighting that many of these buildings and initiatives have been advertised and communicated by *Trastad 2012,* an effort originated from the SNTCS which positions several buildings as good examples, influencing strategies such as Växjö's and Skellefteå's plans (Westerlund, 2012; Skellefteå Municipality, n.d.).

United Kingdom: successful information tools.

During the 1990s, the UK building code was updated to *ease height limit* for multi-story timber buildings. (Table 10) The adoption of a *performance-based code* founded on precedents was also essential to facilitating their development (Mayo, 2015). All TWBs included in this study demonstrated performance values required such as the 9-story Murray Grove – completed in Hackney (London) in 2008. One professional remarked that the building permit was achieved after conducting tests and providing documentation on performance assessment:

> We used the existing *European Technical Approval (ETA)* that KLH had achieved for their product to meet the code requirements for fire, structural performance and thermal. KLH funded acoustic tests to meet the specifics of UK code. This was the only separate test necessary.

Murray Grove's timber structure contributed to lowering the carbon footprint of the project. This reduction – combined with the improved insulation and airtightness – convinced authorities to grant a dispensation from the mandatory *Merton rule* – a policy that obliged generating on-site at least 10% of the energy required to operate the building (TRADA, 2009). One professional argued that the team was able to use the sequestered Carbon within the structure and the carbon savings from not using concrete and steel as part of the carbon reduction strategy.

After the completion of Murray Groove, Hackney Council showed an evident interest in promoting TWBs. One policymaker explained that one planning law in benefit of timber was mooted but not approved. Only a *Timber First* policy focused on providing information was implemented:

Table 10. Categorization and description of policies implemented in United Kingdom.

Policy (or institution)	Level	Description/aim	Policy instruments				
			RI	EI	IT	VPT	RDT
Building Code Update	National	Easing of high limitation for timber structures.	●				
Performance-based code	National	Alternative path to obtaining building approval when performance required is demonstrated.	●				
European Technical Assessment (ETA)	European Union	Documentation on the performance assessment of products not covered by harmonized standards.	●				
Merton rule	Municipal	Planning policy that mandates new projects to produce a minimum of 10% of the energy required for operation from renewable sources on-site.	●				
Timber First Policy (Borough of Hackney)	Municipal	Campaign for the diffusion of benefits of timber construction			●		
Competition (Borough of Hackney)	Municipal	Voluntary competition.		●		●	

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

> We held a conference following the development of Murray Grove and the council planners encouraged its use by talking to developers, architects, etc. […] All one can do is keep the issue in the eye of the development community and promote its benefits in terms of cost, quality of build, time to build, reduced lorry movement, reduction in building, fit out costs, etc.

In a context of wood encouragement by the council for several years, another four TWBs were completed in London, three of them in Hackney. First, the 8-story Bridport House (completed in 2011) followed a design *competition* launched by the Borough of Hackney (Carson, n.d.). Second, the 10-story Cube was built in 2015. Third and last in Hackney, the 10-story Dalston Lane was completed in 2017 in partnership with Hackney's Borough (London Planning Committee, 2017). Finally, the last TWB in London – the 10-storey Trafalgar Place – was constructed in Southwark in 2015.

United States: learning from exemplary projects to updating building codes.

In the United States, timber buildings higher than six storeys are exceptional, as they have to comply with functional criteria (ICC Council, 2006) However, the 7-storey T3 – completed in 2014 in Minnesota – did not need to follow this path. Since the first floor is a concrete podium, the six timber stories allowed the project to be classified under a prescriptive category established in the *Building Code* of Minnesota (ThinkWood, n.d.). In contrast, two other TWBs in Oregon – the 12-storey Framework and the 8-storey Carbon12 – obtained approval through the alternative *Performance-based code*.

The United States Department of Agriculture (USDA) launched in 2015 a competition called *Tall Wood Building Prize Competition* for supporting the development of demonstrative Tall Wood Buildings (McKalip, 2017). (Table 11) The price – granted to Framework – supported R&D activities required for both exploratory phase and to achieving code compliance. The professional team demonstrated fire safety, structural and acoustic performance values (Robinson et al., 2016). Additionally, one professional indicated that the team also conducted assembly tests.

Similarly, the independent non-profit centre Oregon Built Environment & Sustainable Technology Centre launched a *CLT Design Contest Award*. The beneficiary, Carbon12, received support for conducting moisture and acoustic testing (Taylor, 2018). The *Building Approval* was permitted by state offices rather than through Portland city officials. Given the city's interest to promote timber buildings, this procedure lowered the costs associated with its approval (Taylor, 2018).

A policymaker explained that the development of Carbon12 and Framework – along with the Brock Commons in Canada – influenced the edition of the International Building Code (IBC) in the US. Three new classifications for nine, twelve and eighteen storeys were added, based on the latest standards suggested by code experts, the industry, and stakeholders (Breneman et al., 2019).

Policy instruments across projects

This study shows that numerous policies implemented at national, regional and municipal levels facilitated the development of TWBs. These policies acted through one or more Policy Instruments (PIs). Policies based on Regulatory Instruments often acted following this unique mechanism, defining code requirements, restriction easings or zoning planning issues. Because complying with these requirements is challenging and expensive, governments implemented several policies to facilitate the development of TWBs. Remarkably, a number of these policies implemented acted through Economic Instruments, Voluntary Policy Tools and Research and Development Tools simultaneously. Often, competitions or calls for applications (Voluntary Policy Tools) granted projects with subsidies (Economic InstrumentsI) for conducting research and development activities (Research and Development Tools). Per various interviewees and the literature reviewed, these public-private agreements facilitated the developments of

Table 11. Categorization and description of policies implemented in the United States.

Policy (or institution)	Level	Description/aim	Policy instruments				
			RI	EI	IT	VPT	RDT
Minnesota State Building Code	State	Classification of building according to prescriptive definitions.	●				
Performance-based code	State	Alternative path to obtaining building approval when performance required is demonstrated.	●				
Tall Wood Building Prize Competition (TWBPC)	National	Economical support of pilot building for project development and for achieving code compliance. Competition.		●		●	●
CLT Design Contest Award	Independent	Competition for economic support for project development of CLT building.		●		●	●
Building Approval	State	Exceptional building approval granted by state offices.	●				

Notes: RI = Regulatory Instruments; EI = Economic Instruments; IT = Information Tools; VPT = Voluntary Policy Tools; RDT = Research and Development Tools.

TWBs significantly. Complementary, some of these policies acted through Information Tools, providing recommendations of best practices and technical assessments. Other policies focused exclusively on campaigns (Information Tools), as they were conceived as the primary strategy of promotion of TWBs. Exceptionally, Information Tools communicated environmental performance through labelling schemes, indirectly promoting wood use.

Overall, a combination of multiple PIs facilitated the development of TWBs across countries. These PIs were particularly important for developing pioneer projects or taller buildings. Follow-up projects were developed with limited or no governmental support in Austria, Canada and Norway. This study reveals that the existence of technological and legal precedents within countries may explain consecutive cost-competitive projects. The particularities of PIs across projects and countries are presented in Table 12.

Regulatory instruments

The easing of explicit restrictions of TWBs development was crucial for allowing the development of TWBs. This study shows that pioneer projects in Finland, UK and Sweden, were first envisioned after these code updates. Additionally, the adoption of performance-based codes made viable the construction of TWBs. Professionals involved in TWBs developed tests, simulations, and reports for achieving the performance values required. Fire safety was often highlighted as the most relevant barrier; structural and acoustic requirements were also mentioned. In Austria, Canada, Germany, Norway, Sweden, and the United States buildings demonstrated performance primarily after conducting tests. In Finland and Canada, simulations, documentation or reports were also accepted by authorities. In the UK, professionals used one European agreement to provide evidence of performance values demonstrated abroad.

Additionally, zoning planning regulations promoted wood-use in buildings. In Canada (British Columbia Province), one policy mandated timber-use in a project given its public funding source. In Finland, a municipality defined the construction of TWBs in a specific site. Similarly, in Norway and the US, municipal authorities granted buildings with permits under exemptional considerations. In Sweden (Växjö City), a policy mandated wood use in specific areas.

Economic instruments

This study revealed that the industry's lack of experience and complying with regulatory requirements might result in additional costs. In this context, at different administrative levels, public institutions provided economic support for project development of selected TWBs. At all levels, funds were generally directed to support additional research and project development.

Information tools

Policies that acted through Information Tools were implemented for multiple purposes. In Canada, Information Tools provided recommendations of best practices, technical assessments, technical guides, and support for technological tours – often complementing other PIs. In Norway, one policy trained contractors involved in a particular project. In Finland, Canada, Norway, Sweden, and the US, some buildings were developed to demonstrate the potential of timber construction and their benefits. Therefore, projects were conceived to be diffused as exemplary cases. In the UK, a council based its policy strategy on an informative campaign of timber construction benefits, resulting in the majority of TWBs completed in the country. In Austria, and Sweden, labelling schemes were implemented to communicate the environmental performance of TWBs.

Voluntary policy tools

Public organizations generally used policies based on Voluntary Policy Tools for deciding how to assign funds for supporting TWBs. Public competitions and R&D calls provided complementary funding for project development in Austria, Canada, Germany, Norway, Sweden, and the United States. Additionally, policies based on voluntary environmental assessment – such as labelling schemes – influenced projects to use wood in Austria and Sweden.

Research and development tools

This study reveals that Research and Development Tools facilitated the development of TWBs in all the countries examined, except for the United Kingdom. Often, public-private agreements compromised funds for demonstrating code compliance. Moreover, in Austria, Canada, Norway, Sweden and the United States, these grants also funded constructability tests to improve construction processes. Exceptionally in Sweden, these resources also supported the implementation of energy efficiency measures. Notably, some research institutions in Austria, Germany, Norway, Sweden collaborated in many projects as part of the public-private agreements.

Table 12. Impact of Policy Instruments across projects and countries.

	Policy instruments				
Building (country and year)	Regulatory instruments	Economic Instruments	Information tools	Voluntary policy tools	Research and development tools
LCT One (AUT 2012)	Performance-based code: required fire and acoustic tests.	Economic subsidies.		Voluntary application for government support.	Funds for tests for code-compliance. Also, funds for constructability tests. R&D institution collaboration.
Wagramer Strasse (AUT 2013)	Performance-based code. Fire, acoustic, and structural solutions.	Economic subsidies.		Voluntary competition.	R&D activities.
HoHo (AUT 2019)	Performance-based code. Required acoustic and fire tests.		Environmental labelling scheme.	Certification: technical and environmental parameters.	
Wood Innovation and Design Center (CAN 2014)	Performance-based code: fire safety demonstration. Also, acoustic tests. Mandatory wood-use of provincially funded buildings.		Recommendation of best practices.		
Brock Commons (CAN 2017)	Performance-based code: required fire, acoustic, and structural tests.	Economic subsidies.	Technical assessment.	Competition for governmental support.	Funds for tests for code-compliance. Constructability tests.
Origine (CAN 2017)	Performance-based code: required fire and acoustic tests.	Economic subsidies.	Technical assessment.	Competition for governmental support.	Product development. Funds for tests for code-compliance.
Arbora (CAN 2016)	Performance-based code: technical guide accepted as legal precedent.		Technical guide available with solutions.		
The Arbour (CAN 2021–2024*)	Performance-based code: written report to demonstrating fire and structural compliance.	Economic subsidies.	Tours to fabrication plants.	Voluntary application for governmental support.	Constructability tests. Funds for service fees (fire and structural experts).
U of T (CAN 2019*)	Performance-based code.	Economic subsidies.	Assistance of feasibility study.	Voluntary application.	Support of activities (tests, research, and consultation).
Puukuokka (FIN 2015)	Easing of restrictions. Performance-based code: fire safety documentation.				
Lighthouse (FIN 2019)	Performance-based code: simulation of fire safety. Zoning plan benefit.	Subsidy from the City.	City's initiative: demonstration purpose.		
Wood City (FIN 2020)	Easing of wood-use restrictions for TWBs. Performance-based code.			Voluntary competition.	
E3 (GER 2008)	Performance-based code: required components certification and tests.				
H8 (GER 2011)	Performance-based code: required fire tests.	Economic subsidies.		Voluntary application for government support.	Funds for tests for code-compliance. R&D institution collaboration.
H7 (GER 2014)	Performance-based code. Required fire, structural and acoustic performance demonstration.				
C13 (GER 2014)	Performance-based code used E3 building as precedent.				
SKAIO (GER 2019)	Performance-based code.				
SXB B1 (GER 2021)	Performance-based code.				
SXB B2 (GER 2021)	Performance based code.				
Treet (NOR 2015)	Local planning exemption.	Economic subsidies.			Funds for feasibility study.

(*Continued*)

Table 12. Continued.

Building (country and year)	Policy instruments				
	Regulatory instruments	Economic Instruments	Information tools	Voluntary policy tools	Research and development tools
Moholt (NOR 2016)	Performance-based code: required fire safety tests. Performance-based code: required fire safety and structural tests.	Economic subsidies.	Funds for training contractors. Information campaign.	Voluntary application for government support. Voluntary application for government support.	R&D institution collaboration. Funds for tests for code-compliance. Funds for implementing wood-based energy efficiency measures.
Mjøstårnet (NOR 2019)	Performance-based code: required fire safety tests.	Complementary economic subsidies.		Voluntary application for support.	Complementary funds for R&D activities (e.g. assembly process, fire tests).
Limnologen (SWE 2008)	Performance-based code: Fire safety, structural, and acoustic demonstration. Zoning planning: wood-use policy		Promotion of wood construction by local authorities.		
Älvsbacka Park (SWE 2010)	Performance-based code.		Environmental labelling scheme.	Voluntary environmental assessment.	
Portvakten (SWE 2010)	Performance-based code: Fire safety and acoustic demonstration. Zoning planning: wood-use policy.	Economic subsidies.	Promotion of wood construction by local authorities.	Voluntary application for government support.	Funds to supporting design and construction processes. Funds for energy efficiency design measures.
Strandparken (SWE 2015)	Performance-based code: Fire safety and acoustic demonstration.				
Kulturhus (SWE 2021)	Performance-based code.	Economic subsidies.		Voluntary competition.	
Vallen (SWE 2014)	Performance-based code: fire safety and acoustic demonstration. Zoning planning: wood-use policy.		Promotion of wood construction by local authorities.		
Stadthaus (UK 2009)	Easing of Wood-use restrictions for TWBs. Performance-based code: documentation on fire, structural, thermal, values. Also, acoustic test. Energy and environmental performance.				
Bridport House (UK 2011)	Easing of Wood-use restrictions for TWBs. Performance-based code.	Economic subsidy (competition).	Campaign on timber construction benefits.	Voluntary competition.	
The Cube (UK 2015)	Easing of Wood-use restrictions for TWBs. Performance-based code.		Campaign on timber construction benefits.		
Trafalgar Place (UK 2015)	Easing of Wood-use restrictions for TWBs. Performance-based code.				
Dalston Lane (UK 2017)	Easing of Wood-use restrictions for TWBs. Performance-based code.		Campaign on timber construction benefits.		
T3 (US 2014)	Prescriptive category approval.				
Framework (US 2018*)	Performance-based code: Fire safety, structural and acoustic tests.	Economic subsidy.		Voluntary competition.	Funds for code compliance and assembly tests.
Carbon12 (CAN 2018)	Performance-based code. Exceptional approval procedure.	Economic support.		Voluntary competition.	Funds for moisture and acoustic testing.

Notes: AUT = Austria; CAN = Canada; FIN = Finland; GER = Germany; NOR = Norway; SWE = Sweden; UK = United Kingdom; US = United States.

Discussion

This study found a gap in the literature regarding the impact of policies implemented for promoting TWBs. This research classifies policies according to PIs categories presented by Kibert (2001) and analyses qualitatively their impact on TWBs. Therefore, this study mitigates the risks associated with the implementation of further policies with limited or unexpected effects.

(1) Östman and Källsner (2011) indicate that the adoption of performance-based codes (Regulatory Instruments) opened the market for new building products and multi-storey buildings. Moreover, they argue that achieving fire safety through this path is the most significant obstacle. Aligned with this, the results of this research demonstrate that authorities approved all TWBs (except one in the US) through functional criteria. Notably, demonstrating fire safety performance was the most challenging barrier across projects and countries. Yet, authorities also required a relevant number of projects to demonstrate acoustic and structural performance values.

(2) According to Goubran et al. (2019), performance-based codes (Regulatory Instrument) made building codes more flexible, resulting in more experimentation and development. However, they indicated that the latter might increase overall costs. This research confirms these additional expenses. Across all countries studied (except the UK), public institutions implemented policies based on Research and Development Tools, funding additional costs associated with R&D activities. These activities were conducted mostly to facilitating achieving code compliance and improving constructability issues. The latter contradicts FAO (2020) when suggesting that policies may have little impact when mitigating uncertain costs associated with the development of TWBs. This study reveals that not only Research and Development Tools provided support, but also Information Tools. Some policies based on Information Tools funded contractors' training and provided technical assessments – costs otherwise privately financed. One professional in Canada highlighted explicitly that one policy was designed to cover expenses other common projects would not have. Notably, following projects in Austria, Norway, and Canada received very limited or no resources. Professionals indicated that legal and technological precedents – added to their own experience – allowed them developing TWBs with less or no public support.

(3) Vihemäki et al. (2019) indicated that effective Research and Development Tools requires appropriate regulations (Regulatory Instruments), information diffusion (Information Tools) and private interest. They added that PIs might be applied in isolation or combined. In line with the latter, this study shows that Research and Development Tools was implemented effectively in contexts with regulatory frameworks that allowed TWBs in the first place. Explicit restrictions for TWBs and adoption performance-based codes (Regulatory Instruments) occurred without exemption before implementing Research and Development Tools. Moreover, Research and Development Tools granted projects generally through Voluntary Policy Tools, showing relevant private interest. Concerning the applicability of PIs, policies based on Research and Development Tools were usually implemented in combination with Voluntary Policy Tools (competitions or applications) and Economic Instruments (subsidies). In some cases, these policies also considered Information Tools (e.g. campaigns, technical assessments). This study reveals that only Regulatory Instruments instruments and Information Tools were applied in isolation. Regarding policies based on Information Tools exclusively, this research agrees with FAO (2020) when suggesting that campaigns may increase the number of TWBs. Yet, only the UK case confirms the latter. Remarkably, a municipal campaign implemented in isolation promoted several TWBs completed within the country.

Limitations

It is worth noting the methodological and analytical limitations of this research project. This study narrowed the sample buildings by including projects exclusively over six stories and located in 8 countries – limiting the sample size to less than 37 TWBs. The authors recognize that leaving out shorter buildings and other policies across other countries may have resulted in overlooking relevant insights. Due to this, interviewees were asked about precedents (for policies and TWBs) locally and abroad. If appropriate, these were studied and discussed in this research as part of countries' policy frameworks.

Additionally, a limited number of professionals were interviewed, and they may have not being aware of all policies that influenced the projects they participated in. Also, many decisions may have been taken before their involvement. Furthermore, policymakers

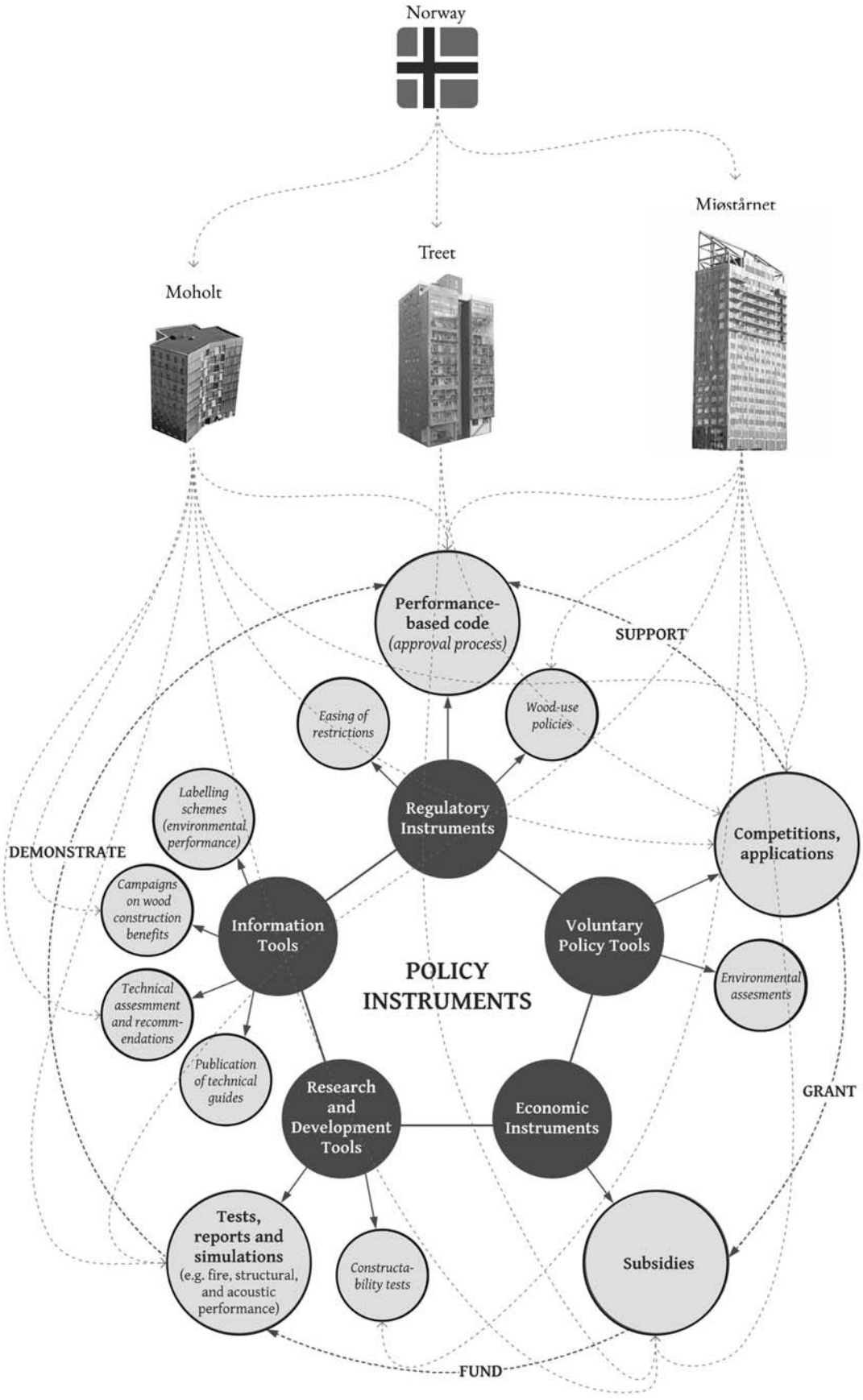

Figure 4. Summary of Policy Instruments implemented across countries. To exemplify their impact, the diagram illustrates the relationship between Policy instruments and individual Tall Wood Buildings developed in Norway.

Source: Google Earth (Moholt), M. Ramage (Treet), Moelven (Mjøstårnet).

interviewed may not be able to identify all TWBs policies impacted, neither how the policy influenced individual projects. For this reason, policymakers and professionals' answers were often contrasted with each other. Also, when possible, the information provided was compared and complemented with documentary data review.

Conclusions

The analysis of policies and their impact on Tall Wood Buildings (TWBs) is a subject that has not been discussed broadly in the literature. Most of the scholarship available focuses on policies that are indifferent to the height of the structures or examine exclusively regulatory issues. Only a few publications analyse the connections between policies and individual TWBs. Furthermore, there is a gap in the literature concerning the mechanism of action of these policies – the Policy Instruments (PIs). Through the analysis of the impact of policies on 37 TWBs across eight countries in Europe and North America, this paper examines the influence of particular PIs across projects (Figure 4).

The findings reveal that one or more PIs impacted all TWBs studied. Regulatory Instruments – mostly related to explicit restrictions and performance-based code compliances – were generally identified as the primary barrier. Later – through Research and Development Tools – many governments provided support for conducting innovation activities to comply with these regulations and improve constructability issues. Numerous institutions granted projects with subsidies (Economic Instruments) after calls for competitions or applications (Voluntary Policy Tools). Information Tools (e.g. campaigns and technical assessment) often complemented these grants or were implemented in isolation. Remarkably, some follow-up TWBs were developed with limited or no policy support. Overall, these findings may be useful for policymakers for designing policies to facilitating the development of TWBs. Understanding policies that have impacted effectively on TWBs evidence the obstacles the industry is facing; and therefore, the potential role that public institutions may have on their development.

Notes

1. The development of taller buildings is progressing rapidly, yet this research focuses exclusively in projects completed, under construction or planned at the moment.
2. Kibert's (2001) categories are used for this research because they focus on issues applicable specifically to the built environment.
3. Some provincial codes are being revised to allow buildings up to 12 storeys (e.g. Shelby, 2019).

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