

Optimization of Production Efficiency in Home Construction

Reported by:

Duannaelba Arone

Karen Beltran

Kurai Madzonga

Rajanbir Singh

Sunil Sundrapalyam

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Introduction

- The construction Industry is poised for a significant shift toward automation, mirroring trends seen in manufacturing.
- Integrating robotics into prefabricated construction represents a significant shift in the construction industry, leveraging advanced automation to optimize manufacturing, transportation, and assembly processes
- Prefabrication, which involves producing building components in a controlled manufacturing environment before transporting them to the construction site for assembly, is becoming widely adopted due to its inherent productivity, accuracy, and safety while reducing costs and environmental impact.
- This article examines the technical integration of robotics in prefabricated construction, highlighting specific applications, advantages, challenges, and the overall impact on the construction efficiency and cost structure.
- Factory-built (modular/prefab) home construction offers significant advantages over traditional **stick-built** methods in terms of **waste reduction, safety, construction time, and cost**, making it a viable solution for **affordable housing**.
- The controlled manufacturing environment allows for the application of lean principles, which streamline the process and eliminate many wastes inherent to on-site construction.

Value Stream Analysis & Waste Reduction

A Value Stream Mapping (VSM) analysis of home construction, from raw material to customer delivery, clearly shows the inherent efficiency of factory-built methods compared to stick-built.

Waste Area (Muda)	Stick-Built (On-Site) Construction	Factory-Built (Modular/Prefab) Construction	Lean Solution
Defects	Exposure of materials to weather, inconsistent assembly, varying skill levels of on-site crews. High rework rate.	Controlled, indoor environment; standardized workstations; use of specialized equipment; rigorous in-factory quality control. Low rework rate.	Standardized work, Poka-Yoke (mistake-proofing), Total Quality Management (TQM).
Inventory	Excess materials ordered due to theft/damage risk, inconsistent supply chain, bulk delivery before needed.	Bulk purchasing with just-in-time (JIT) delivery to factory line; secure, climate-controlled storage; materials kitting at workstations.	JIT inventory control, material kitting, kanban for material flow.
Overproduction	Building components on-site before they are needed or before previous work is ready (e.g., framing before foundation cures).	Production leveled to Takt time (customer demand rate); modular sections are built only as needed for final assembly schedule.	Takt Time, Production Leveling, Pull System.

Waiting	Delays from weather (rain, snow, extreme heat), waiting for trade contractors (plumbers, electricians) to complete their part, inspection delays, material shortages.	Factory work continues regardless of weather ; all trades are full-time employees on the assembly line; multiple processes (foundation and factory build) occur simultaneously .	Synchronized flow, parallel processing (site work & factory work), Elimination of weather-related downtime .
Transportation	Frequent trips by subcontractors, site managers, and material suppliers to the decentralized site.	Centralized facility minimizes material movement (raw material to finished module); single delivery of finished modules to the site.	Optimized factory layout (line-back principle), centralized logistics .
Motion	Workers walking long distances on the large, unorganized job site to fetch tools and materials.	Workers have specialized, ergonomic workstations with all necessary tools/materials immediately at hand (5S workplace organization).	5S (Sort, Set in order, Shine, Standardize, Sustain), ergonomic design of workstations.
Over-processing	Re-measuring, re-cutting materials on-site due to standard material sizes not matching on-site needs.	Precision cutting of materials to exact specifications using factory machinery, maximizing yield and fit.	Digital modeling, precision machinery, waste material recycling/reuse programs .

Automation machinery is extensively used in factory- built (modulars) homes for precision cutting, assembly, and material handling, resulting in faster construction, reduced waste, enhanced worker safety and higher quality control compared to traditional stick-built construction, which relies more heavily on manual labor and is more susceptible to weather delays and human error.

Automation in factory built homes uses industrial robots, CNC machines and AI-driven systems to produce high quality, consistent, and customizable components with minimal waste, significantly faster than traditional stick built methods.

In summary, modular construction **significantly reduces waste** (up to **90% less construction and demolition waste**) by using controlled environment, precise material ordering, and assembly-line efficiency.

Worker Safety and Workers' Compensation Claims

Manufacturing a home in a factory **positively impacts** contractor and employee workers' compensation claims by creating a significantly safer work environment.

Method with the Lower Rate of Injury

Factory-built construction has a **lower rate of injury** for the following reasons:

- **Elimination of "Fatal Four" Hazards:** The majority of work is done at ground level, drastically reducing the risk of **falls** (the leading cause of construction fatalities).
- **Controlled Environment:** Work is performed **indoors**, eliminating weather-related hazards (slippery surfaces, heat exhaustion, high winds).
- **Standardized Work:** The assembly-line process involves specialized, repetitive tasks, which leads to **fewer errors** and a higher adherence to safety protocols.
- **Reduced Site Traffic:** Fewer workers and heavy machinery are present on the final assembly site, lowering the risk of being **struck by an object** or **caught-in/between** incidents.

While the on-site setting of traditional **stick-built** construction is inherently dangerous (often ranking highest for fatal injuries), the final on-site *setting* for factory-built homes can have unique, though less frequent, hazards related to the **lifting and assembly of multi-ton modules** via cranes, which requires stringent safety control. However, the vast majority of the construction time (and thus man-hours) is spent in the much safer factory setting.

Labor Safety and Compensation Claims

Injury Rates and Fatalities

Type of Construction	Injury Rate (per 100 workers)	Annual Fatalities (Canada-wide)	Source
Traditional	3.5 – 4.0	1,056 (2023)	AWCBC, 2023; The Safety Mag, 2023
Prefabricated	~0.8 (80% reduction)	Significantly fewer (no exact data)	Canadian Contractor, 2021

- Traditional construction in Ontario alone recorded **264 fatalities** and **65,566 lost-time injury claims** in 2022–2023 (Ontario Ministry of Labour, 2023).
- In Alberta, **55% of compensation claims** come from workers with less than one year of experience (WCB Alberta, 2023).

Compensation Claims and Safety-Related Costs

- Modular construction minimizes onsite hazards by centralizing work in controlled factories, reducing exposure to silica dust, solvents, and VOCs common in traditional sites (MDPI, 2022).
- Traditional sites bear higher costs for personal protective equipment, training, and onsite safety enforcement (MDPI, 2022).
- Safety surveys reveal **100% of modular contractors** report positive safety impacts: 11% medium, 39% high, and 50% very high (Stack Modular, 2021).

Regional Trends in Canada (Including Alberta Case Study)

Province	Avg. Cost per Injury Rate (per sq. ft. (CAD) 100 workers)		Construction Fatalities (latest year)	Source
Alberta	\$120 – \$280	3.5	30	WCB Alberta, 2023
British Columbia	\$150 – \$300	4.0	39	ConstructConnect, 2023
Ontario	\$130 – \$310	3.8	264 (2022–2023)	Ontario Ministry of Labour
Saskatchewan	\$110 – \$260	3.95	15	AWCBC, 2023
Quebec	\$105 – \$275	3.7	25	Provincial Labor Ministries
Maritime Provinces	\$105 – \$275	3.2	10	Provincial Labor Ministries

Alberta Case Study:

Alberta exhibits injury rates and fatalities consistent with national averages. The province has seen **55% of compensation claims from workers with less than 1 year experience**, emphasizing the importance of improved safety training (WCB Alberta, 2023).

Impact of Safety Issues on Construction Companies

- Poor safety records in traditional construction have led to company closures, such as **Bondfield Construction Co. Ltd. (Ontario, 2019)** and **R.M. Bélanger Ltd. (Ontario, 2022)**.
- Insolvencies in the construction sector increased to **569 in fiscal 2024**, up from **370 in 2023** (Ontario Construction News, 2024).
- Heavy fines imposed on firms for safety violations, e.g., two Calgary companies fined **CAD \$168,000 each** in 2025 (HR Law Canada, 2025).

Construction Time Comparison

Depending on the type of construction, construction time from design to handover varies based on several factors, including weather, permitting, design, site preparation, logistics, and others. Therefore, in this module, the methods of off-site and on-site construction will be explained, and the steps involved in each process will be described. Additionally, a detailed analysis of the construction time for some projects in Canada will be provided, along with a conclusion.

A factory-built home can be constructed incredibly fast; however, the claim of "**1 week**" generally refers only to the **in-factory assembly time** or the **on-site setting/assembly of the modules** (often taking a few days), not the entire build process.

Construction Method	Typical Total Timeline (Design to Move-in)	Comparison
Factory-Built (Modular/Prefab)	3–6 months (average)	Significantly faster —typically reducing total project time by 30–70% .
Stick-Built (On-Site)	9–18 months (average)	Prone to delays from weather, labor shortages, and unexpected on-site issues.

Definitions

Off-site Construction (Factory-Built or Modular): This method involves planning, designing, manufacturing, and assembling building components in a controlled factory environment before they are transported to the project site for final assembly, commissioning, and handover. In Canada, off-site construction typically employs modular units and prefabricated panels constructed from lightweight wood frames or mass timber, which are assembled in a controlled factory environment that supports operations throughout the year. Figure 1 illustrates the block diagram of the steps in a typical off-site home construction process, and Figure 2 provides an example of a Factory Production Stage, which includes panel fabrication, module assembly, MEP (mechanical, electrical, and plumbing) installation, interior finishing, and quality inspection. All these steps are carried out in a climate-controlled working environment.

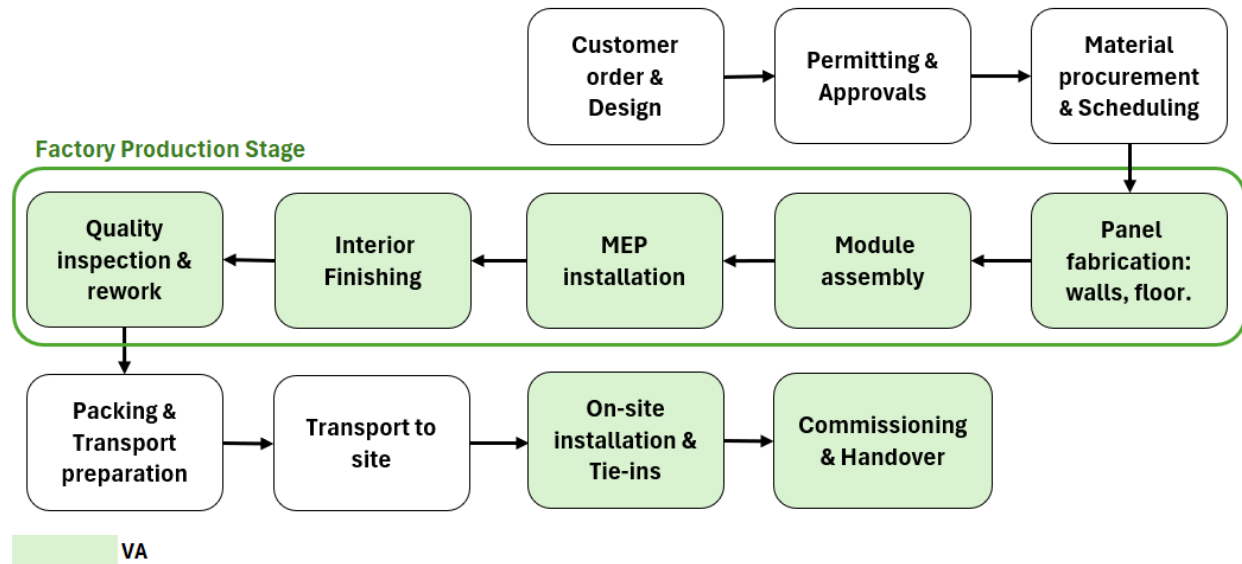


Figure 1: Off-site construction process

It is essential to note that in factory-built home construction, the site preparation and foundation processes can be completed in parallel with the factory production stage. For example, in the North Ridge Project, a 42-unit apartment complex located in St. Albert, Alberta, the foundation and site preparation process required 3.5 months of work. The factory production stage took 4.75 months, and the remaining processes took an additional 2 months. In that way, this complex was built in 6.75 months. A real-world case study that demonstrated the benefits of factory-built construction in terms of time compared to on-site construction.

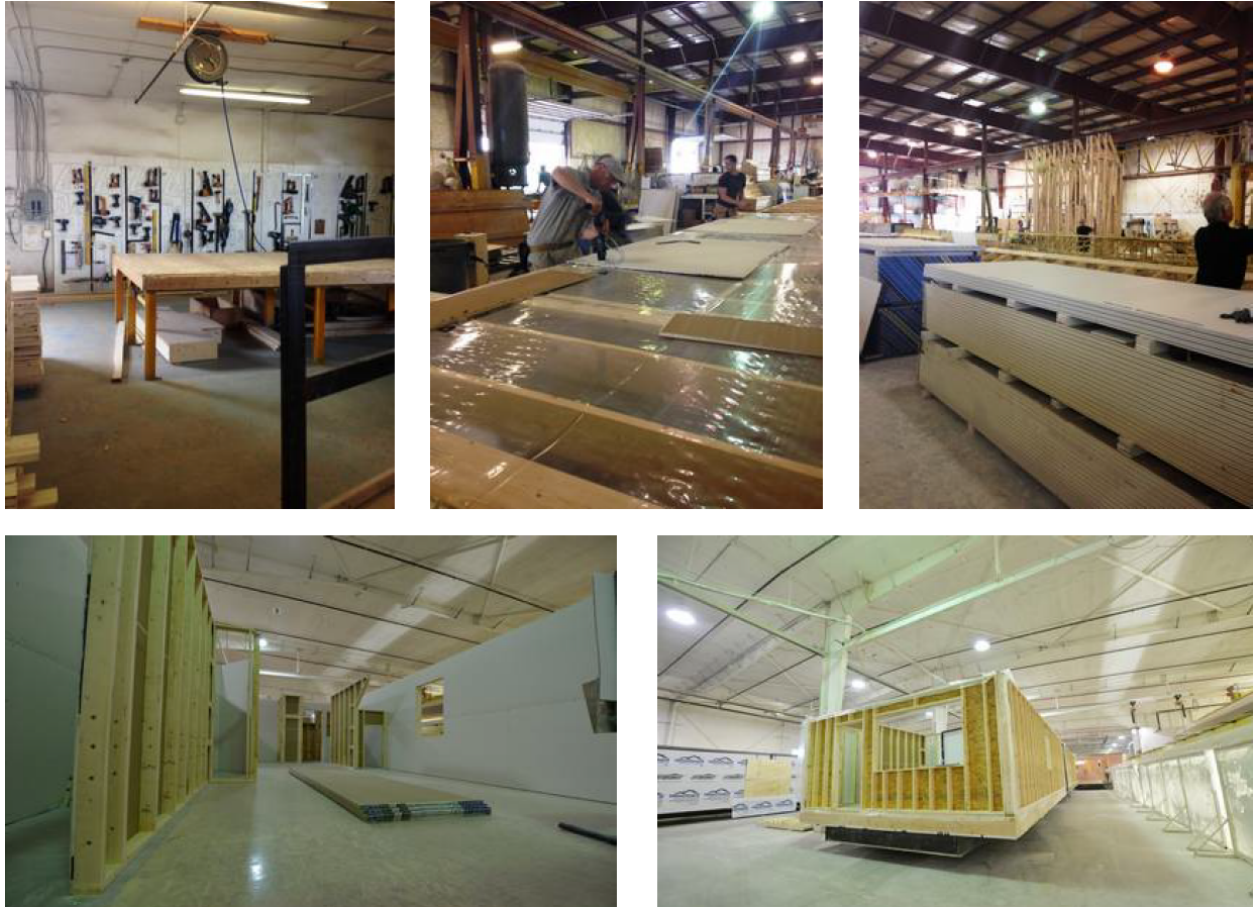


Figure 2: Factory Production Stage

On-Site Construction (Conventional): This method is a sequential process of constructing all structural and finishing elements directly on-site. Figure 3 illustrates the block diagram of the steps involved in an on-site home construction process.

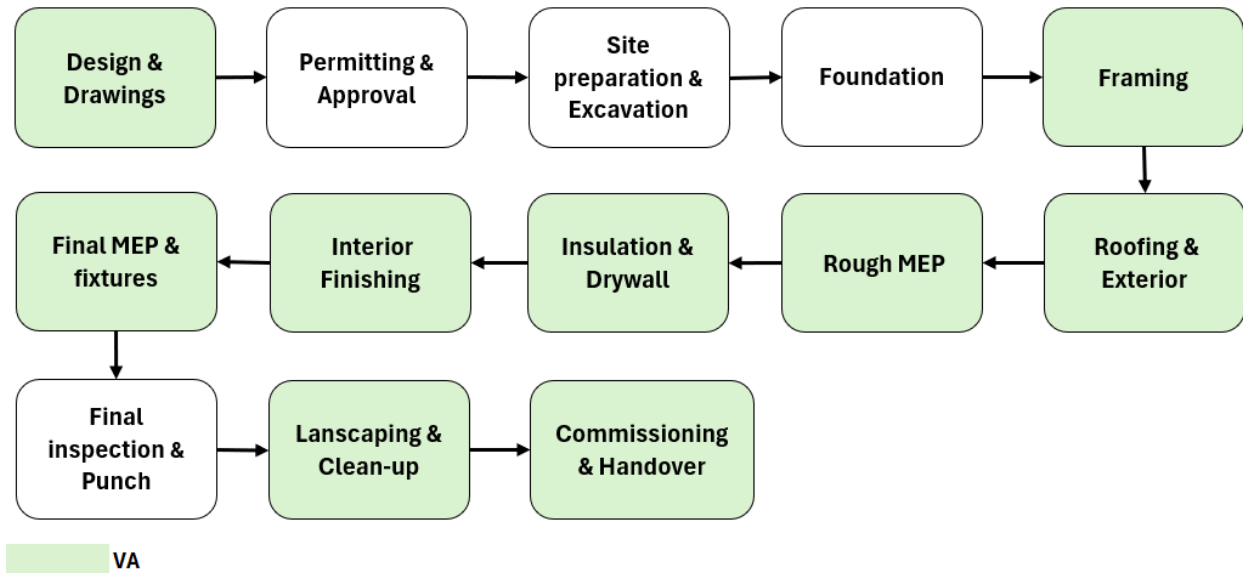


Figure 3: On-site home construction process

The sequential process means that it is not possible to proceed to the next step without completing the previous one. For the North Ridge Project, if on-site construction had been chosen, the work time for foundation and site preparation would be the same, 3.5 months. However, the next steps, from framing until commissioning and handover, would take another 11.75 months.

Construction time comparison between factory-built and on-site built in Canada

According to Table 1, projects realized in different regions of Canada from 2020 to 2024 consistently demonstrate a 35-55% time reduction in factory-built construction compared to the traditional method of on-site construction for various housing types, including single-family, multi-unit, modular pilot, and mass timber modular projects.

Table 1: Construction time comparison between factory-built and on-site built homes in Canada

Source	Year	Project category	Factory-built	On-site	Reduction time
Canada Mortgage and Housing Corporation (CMHC) — Modular Construction Report	2023	Multi-unit housing (Ontario, Alberta, BC)	16–24 weeks	32–50 weeks	40–55% faster
Modular Building Institute (MBI Canada Chapter)	2022	Single-family and low-rise multi-family	14–22 weeks	30–45 weeks	35–50% faster
University of British Columbia (UBC) — Prefabricated Housing Study	2021	Prefab wood-frame homes, BC	20 weeks	36 weeks	~45% faster
Alberta Innovates & Alberta Modular Association Report	2020	Modular housing pilot projects, Alberta	18–26 weeks	40–52 weeks	35–55% faster
Government of Ontario — Housing Innovation Report	2024	Affordable modular housing, Toronto & Ottawa	5–6 months	9–12 months	40–50% faster
Canadian Wood Council / FPInnovations	2022	Mass timber modular projects	24–28 weeks	48–56 weeks	~50% faster

Construction Phases considering the impact of wintertime in Canada

The following table highlights the differences in duration between factory-built and on-site construction processes, as well as the weather impact (winter) on each phase.

Table 2: Construction Phases considering the impact of wintertime in Canada

Construction Phase	Factory-Built	On-Site	Weather Impact (Winter)
Pre-Construction (Planning, Design, Permits)	1–3 months (Simultaneous to factory planning)	4 months	Minimal impact on planning, but permit speed can vary.
Site Prep & Foundation	1–2 months (Typically Late Fall to minimize cost)	1–2 months	High Risk: Requires ground thawing/heating for concrete; susceptible to freeze/thaw cycle damage.
Structural Construction (Framing, Roofing, Exterior Envelope)	1–4 months (Factory) (Simultaneous)	3–4 months	Extreme Risk: Productivity loss up to 50% due to cold, snow, and safety issues on-site.
Transportation & On-Site Assembly (Craning)	1–2 days (On-Site)	N/A	Low impact: craning can proceed safely in most Alberta winter conditions, and the structure is quickly sealed.
Rough-in/Finishing (Plumbing, Electrical, Drywall, Paint)	1–2 months (On-Site Final Finishes)	3–5 months (Interior)	Interior work can continue with temporary heat, but material delivery and worker breaks still cause delays/cost increases.
Total Project Duration	6–8 months	9–12 months (Production) to 10–16 months (Custom)	Conventional: Highly susceptible to a 2–6-month delay if structural work hits winter. Modular: Highly insulated from seasonal risks.

In summary, factory-built construction typically reduces project delivery time by 35-55% compared to on-site building. This benefit primarily stems from the parallel workflow, where site preparation and foundation, as well as factory production, occur simultaneously, which is crucial for reducing work time. Additionally, the controlled factory environment enables the development of projects year-round, and the manufacturing production allows better efficiency and logistical coordination. Due to these significant benefits, factory-built home construction is increasingly viewed throughout Canada as a fast, reliable, and resilient option, particularly suitable for projects during the winter months.

The speed difference is primarily because the **foundation/site preparation** and the **home module construction in the factory** occur **simultaneously** (parallel processing). In contrast, site-built construction is a sequential process where one major step must be completed before the next can begin.

Cost Per Square Foot Comparison

The cost to build a **1,200 sq ft, 3-bedroom factory-built home per square foot is generally lower** than a similar on-site built home.

- **Factory-Built Cost:** Modular homes typically cost between **\$80 and \$250 per square foot** (excluding land and utility connection costs). A 1,200 sq ft home would cost roughly **\$96,000 to \$300,000** for the home structure.
- **Stick-Built Cost:** Traditional site-built homes are generally **20–30% more expensive** than modular homes.

This report provides a detailed analysis of the cost per square foot for home construction in Canada, focusing on basic, average, and mid-range finish levels. It forms part of a team-based project analyzing the efficiency, cost, and waste reduction potential of factory-built (factory-built) versus traditional stick-built homes.

The goal is to establish reliable Canadian cost benchmarks and assess how production efficiency can contribute to affordable housing solutions.

Methodology and Data Sources

Data for this report was gathered from credible Canadian sources such as:

- Canada Mortgage and Housing Corporation (CMHC)
- Statistics Canada (StatCan)
- Altus Group Cost Guide
- Regional cost estimates from Wowo.ca, RE/MAX Canada, and Buildable.ca reports.

The analysis compares construction costs (excluding land) per square foot across provinces. Figures represent early 2025 market conditions for detached homes with standard materials and finishes.

Provincial Cost Comparison

The following chart and table compare average construction costs for basic and mid-range homes in major Canadian regions. These values reflect typical builder prices per square foot for standard, single-family homes.

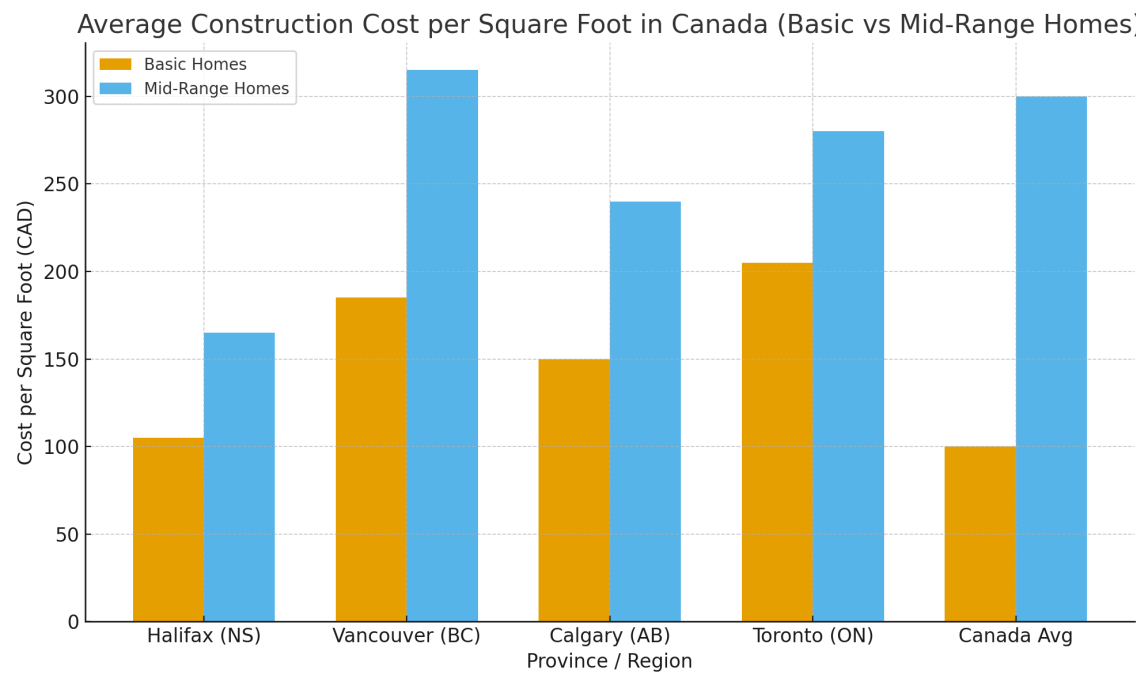


Table 1. Average Construction Cost per Square Foot (CAD):

Province / Region	Basic (Low Range)	Mid-Range (High Range)
Halifax (NS)	\$105	\$165
Vancouver (BC)	\$185	\$315
Calgary (AB)	\$150	\$240
Toronto (ON)	\$205	\$280
Canada Avg	\$100	\$300

Regional Cost Analysis

- **British Columbia (BC):** The highest construction costs in Canada due to strict building codes, high labour rates, and limited land supply. Mid-range homes average between \$275–\$450 per sq ft in Metro Vancouver.
- **Alberta:** Moderate construction costs, averaging \$150–\$240 per sq ft. Calgary and Edmonton benefit from competitive labor and material pricing due to active construction industries.
- **Ontario:** Broad range from \$130–\$400 per sq ft depending on customization. GTA areas have higher costs driven by demand and urban density.
- **Atlantic Provinces:** Among the lowest costs nationally (around \$105–\$165 per sq ft) due to lower wages and reduced demand pressures.

Example Cost Comparison — 1,200 sq. ft Home

The table below illustrates how total construction cost varies by region for a standard 1,200 sq. ft. home.

Region	Cost per sq ft (Basic)	Cost per sq ft (Mid-Range)	Estimated Total Cost Range
Atlantic Canada	\$105	\$165	\$126,000 – \$198,000
Alberta	\$150	\$240	\$180,000 – \$288,000
Ontario	\$205	\$280	\$246,000 – \$336,000
British Columbia	\$185	\$315	\$222,000 – \$378,000

Factors Affecting Cost per Square Foot

Several factors influence the cost per square foot of home construction across Canada:

1. Labor and trades availability — Scarcity increases costs in high-demand markets.
2. Material supply and logistics — Remote regions face higher shipping and delivery costs.
3. Design complexity — Custom homes increase cost per square foot.
4. Energy codes and building standards— Updated regulations, especially in BC and Ontario, add cost layers.
5. Construction method — Stick-built homes may face more weather-related delays and inefficiencies.

Stick-Built vs Factory-built Construction Cost Analysis

Factory-built often demonstrate cost efficiency compared to traditional stick-built construction.

While site-built homes in Canada typically range from \$150–\$300 per sq ft, factory-built can cost 10–25% less due to standardization, controlled production environments, and reduced material waste.

Advantages of Factory-built Construction:

- Reduced weather delays and rework costs.
- Lower material waste (estimated 30–50% less).
- Shorter project timelines (assembly in 1–2 weeks).
- Lower worker injury rates due to controlled environments.

Challenges:

- Transportation and crane setup costs for remote sites.
- Limited design flexibility.
- Zoning and permitting restrictions in certain municipalities.

The analysis confirms significant provincial variation in construction cost per square foot across Canada. Factory-built housing demonstrates measurable advantages in cost stability, efficiency, and safety outcomes. If supported by zoning policies, factory-built construction could play a vital role in providing affordable housing for growing Canadian communities.

The lower cost per square foot for factory-built homes is due to:

1. **Efficiency of Scale:** Bulk purchasing of materials and use of assembly line production lowers material and labor costs.
2. **Waste Reduction:** Less material waste translates directly to lower purchasing costs.
3. **Reduced Labor Hours:** Faster construction means less accrued labor time and lower financing costs.

Impact on Affordable Housing

Factory-built homes offer a powerful solution for providing more affordable housing to communities.

The core efficiencies of factory-built construction directly address the primary drivers of the affordable housing crisis:

- **Reduced Costs:** Modular homes are consistently sold at a **lower price point** than comparable stick-built homes, making them more accessible to first-time buyers and low-to-middle-income families.
- **Speed and Scalability:** The ability to mass-produce high-quality homes quickly allows builders to respond to high demand and **increase housing supply faster** than traditional methods.
- **Favorable Financing:** Buyers of modular homes are **disproportionately more likely** to use government-backed financing (FHA/VA loans) because they tend to be first-time buyers with lower incomes, indicating a greater need for and reliance on the affordability this construction method provides.
- **Urban Infill:** Modular construction is also effective for Accessory Dwelling Units (ADUs) and multi-family projects, supporting **urban densification** which is crucial for affordability in high-demand urban areas.

This impact is realized through multiple interconnected efficiencies across the total cost of ownership and the ability to rapidly increase housing supply.

Lower Total Cost of Ownership

The affordability of factory-built homes extends beyond the initial purchase price to cover long-term costs, making them genuinely accessible to a wider range of low- and middle-income buyers.

a. Reduced Construction Costs

Factory-built homes are generally **10% to 40% cheaper per square foot** than comparable stick-built homes, with an average construction price range often lower than traditional methods.

This is due to:

- **Mass Production Efficiencies:** Factories utilize assembly-line techniques, bulk purchasing of materials, and standardized designs (catalogs) to achieve economies of scale.
- **Lower Labor Costs:** Building in a fixed location allows manufacturers to employ a stable, non-unionized workforce, often at lower rates than specialized on-site trade subcontractors.
- **Minimized Waste and Theft:** Precision manufacturing drastically reduces material waste (up to 90% less waste) and eliminates job-site material theft and damage from weather.

b. Energy Efficiency and Utility Savings

Factory-built homes often have a **lower operational cost** due to superior insulation and construction quality.

- **Quality Control:** The indoor, controlled environment ensures tighter construction, resulting in a more effective thermal envelope and superior air-tightness.
- **Lower Bills:** This high level of energy efficiency means the home requires significantly less energy for heating and cooling, leading to lower monthly utility bills, which is a critical factor in a homeowner's total debt-to-income ratio (affordability).

Rapid and Scalable Supply Increase

The single greatest driver of housing affordability is **supply**. Factory construction directly addresses supply shortages by enabling a faster, more predictable build cycle, allowing communities to house people quicker.

a. Accelerated Project Timelines

Modular construction can **reduce total build times by 20% to 50%** compared to traditional methods.

- **Parallel Processing:** Site work (foundation, utilities) and module construction happen **simultaneously**. In traditional building, these are sequential, leading to months of delays.

- **Weather Immunity:** Construction is completed year-round, eliminating weather delays, which is especially critical in regions with short or harsh building seasons (e.g., northern communities).

b. Capacity for Mass Production

Unlike stick-building, which is limited by local labor and site conditions, factories can **replicate units at scale**. This repeatable, industrial process allows non-profit organizations and municipalities to commission hundreds of similar units efficiently, directly aiding large-scale affordable housing initiatives (e.g., transitional housing, subsidized rental communities).

Compatibility with Government Initiatives

Factory-built homes are a strategic tool that aligns perfectly with modern government initiatives designed to solve housing crises.

a. Housing Crisis Intervention

Government programs, such as the **Rapid Housing Initiative**, specifically leverage modular construction's speed to deliver housing quickly to vulnerable populations, including those experiencing homelessness or in need of transitional housing. The rapid deployment helps communities respond immediately to urgent needs.

b. Infill Development and Density

Modular construction is ideal for **urban infill** (developing vacant lots or underutilized land within established neighborhoods).

- **Reduced Disruption:** Because 80–90% of the work is done off-site, the on-site construction period is short (often days for assembly), minimizing noise, traffic, and neighborhood disruption.
- **Site Flexibility:** Modular units can be designed to fit the small, irregularly shaped lots common in urban infill, allowing for the quick creation of new, affordable density in areas where it is most needed.

c. Access to Favorable Financing

Governments and lenders are increasingly offering programs tailored to the benefits of factory-built housing:

- **Energy-Efficiency Incentives:** Because modular homes are often built to high performance standards, they frequently qualify for government-backed "**green loans**" or grants, which can lower a buyer's interest rate or reduce their initial capital outlay.
- **Subsidized Programs:** For non-profit and community housing providers, modular projects often meet the criteria for federal and provincial affordable housing funds and loan programs, securing the financing needed to keep rents and sale prices below market rates.

Conclusion

Final Summary Comparison – Factory-Built vs. Stick-Built Homes

Factor	Stick-Built (On-Site)	Factory-Built (Modular/Prefab)	Advantage
Cost per Sq Ft	\$150–\$300	\$80–\$250 (10–25% lower)	Factory-Built
Construction Time	9–18 months	3–6 months (30–70% faster)	Factory-Built
Material Waste	High due to rework and weather	Up to 90% less waste in factory environment	Factory-Built
Worker Injury Rate	3.5–4.0 per 100 workers	~0.8 per 100 workers (80% lower)	Factory-Built
Weather Delays	Frequent; winter slows projects by 2–6 months	None; year-round indoor production	Factory-Built
Labour Requirements	Multiple subcontractors; weather-dependent	Centralized, skilled labour in controlled setting	Factory-Built
Quality Control	Inconsistent; dependent on on-site crew	Standardized inspections, digital precision	Factory-Built
Environmental Impact	Higher waste and energy use	Reduced emissions and waste; energy-efficient builds	Factory-Built

Affordability Outcome	High overall build and financing costs	10–40% lower total ownership cost	Factory-Built
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Data-Based Conclusion

Analysis from CMHC, StatCan, and Altus Group confirms that factory-built housing can reduce construction costs by 10–25% per sq. ft and shorten total project timelines by 35–55%.

Controlled factory environments eliminate weather delays, reduce injury rates by over 80%, and lower material waste by up to 90% through precision cutting and just-in-time (JIT) production.

In provinces such as Alberta and Ontario, modular construction projects have demonstrated completion times under 7 months compared to 12–18 months for traditional builds, even accounting for permitting and foundation work. These operational efficiencies directly support affordability, enabling quicker occupancy, reduced financing costs, and lower long-term ownership expenses.

Final Finding

Factory-built homes offer a data-proven advantage for addressing Canada’s housing affordability and sustainability challenges. Municipalities that adopt modular development policies can expect lower costs, faster delivery, and safer, greener construction outcomes, making factory-built housing an essential component of the next generation of residential development.

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