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# ANALYSIS OF PREFABRICATED CONSTRUCTION: PRODUCTIVITY, BENEFITS, RISKS & APPLICATIONS IN CANADIAN PERSPECTIVES

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**Abstract:** This study analyzes the productivity of prefabricated construction methods with respect to cost and time. In addition, this study explores the main benefits and applications of prefabricated construction methods as well as identifies the major risks that could affect their use in Canada. Several interviews with experienced construction professionals were conducted. Also, surveys were conducted choosing construction managers, tradespeople, and construction workers who are familiar with prefabricated construction. The responses from construction professionals revealed that prefabricated construction methods are more advantageous than conventional construction methods due to reduced construction time, cost, and site waste. The interview results indicated that prefabrication construction methods take about 3 to 4 weeks per townhouse unit and can save around 4 to 8 weeks. Furthermore, the survey results exhibited that prefabricated construction methods decrease the overall project delivery time. The survey results also imparted that faster project delivery time and reduced labourers on site are the two most important factors, which decrease the cost of prefabricated construction. The other benefits of prefabricated construction methods are minimum risk of injury and minimization or total elimination of on-site wet trades, which became obvious from the interview results. Despite having manifold benefits, there are some risks of using prefabricated construction methods, such as fabrication errors, damage during transportation, misfits on worksite, and delays due to the shortage of skilled labourers and changed orders. Yet prefabricated construction methods are being used in Canada in the cases of trusses, exterior wall components, framing elements, and MEP (mechanical, electrical, plumbing) systems.

## 1 INTRODUCTION

Prefabricated home construction has had a long history in North America. One of the best-known early kit-home sellers was Sears, Roebuck and Co. which sold more than 100,000 homes from 1908-1940 (Connors, 2012). Bernstein et al. (2011) found out through one of their surveys that exterior walls and MEP (mechanical, electrical, plumbing) systems were the most common building elements for which the respondents used prefabrication techniques. Their survey results revealed that 48% of the respondents in each category reported the use of prefabrication techniques for exterior walls and MEP systems. In fact, contemporary prefabricated homes are also catering to the upscale residential construction market. Today's prefabrication companies emphasize the design and green technology aspects of the construction industry (HowStuffWorks, 2013).

Northeast Country Homes (2012) claims that residential prefabricated construction requires less intensive and skilled labourers, because the parts come preassembled. This increases the productivity of the construction project by cutting on the cost of labour. Further cost savings are also derived from the fact that the builder is not required to pay for the health and safety of too many labourers present on construction site, since most workers are used in making the building modules off site by a separate

company. Bernstein et al. (2011) concluded from their surveys on the productivity of prefabricated construction methods that 65% of the respondents noticed a decrease in budget, 66% indicated a positive impact on project schedule, with 35% of those respondents estimating that the project time can be reduced by up to four weeks. They also found from surveys that 77% of the prefabrication users reported a 44% reduction in construction site waste, resulting in further cost savings.

Rippon (2011) described that in North America, site-built homes usually require materials to be shipped to the worksite in advance, resulting in more time; whereas prefabricated construction uses building modules that come preassembled, thereby saving time. He also explained that prefabricated building components are protected from weather related delays due to indoor assembly of the modules. Furthermore, Modular Building Institute (2011) determined that using prefabricated construction methods takes 35% less time on average during the building construction stage. Burrows (2013) identified that prefabricated construction practice greatly contributes to more sustainability and higher productivity in the residential construction industry since it generates minimum construction waste. On prefabricated construction projects, the amount of waste and the contamination to the worksite are significantly lowered, thereby greatly reducing the time for the site restoration stage.

Prefabricated construction is increasingly being adopted worldwide to enhance productivity and to alleviate the adverse environmental effects that result from conventional construction activities (Li et al. 2014, Chang et al. 2018). In a survey conducted by Bernstein et al. (2011), the most common reason cited by contractors for using prefabrication techniques was “to improve productivity” with 92% of the respondents citing this reason. The productivity of prefabricated construction methods depends on project size. In general, it is quite true that the smaller the construction project, the harder it is to achieve significant improvement in the productivity with prefabricated construction methods as opposed to conventional methods. Wiedemann (1990) studied the cost-effectiveness of prefabricated construction projects in Montreal area; according to his study, the home builders of single detached homes reported that prefabricated residential homes were 10% more expensive than conventional homes. He cited a high start-up cost as one of the main reasons for the increased cost. On large-scale construction projects such as when building sub-divisions, the increase in initial start-up cost can be offset by the reduction in time to complete a sub-division. On large-scale projects - where the design stage, permits and approvals stage, and site development stage only need to be completed once - the building construction stage represents the biggest time-consuming factor. In terms of the productivity variation by firm size, Bernstein et al. (2011) found that more medium to large firms (47%) reported a schedule decrease of four weeks or more compared to small firms (9%).

The basic attributes and advantages of prefabricated construction have been narrated above. However, the efficacy of prefabricated construction technology with regard to project delivery time and project cost as well as the benefits and risks of this technology needs to be analyzed for its broad applications in Canada. The aim of this study is to analyze the difference in productivity between prefabricated and conventional construction methods, particularly in residential sector. The specific objectives of the study are to 1) examine the productivity of prefabricated construction methods versus conventional construction methods with respect to construction time, 2) compare the cost savings of prefabricated construction methods over conventional construction methods, 3) realize the benefits as well as the risks associated with prefabricated construction techniques, and 4) recognize the applications of prefabricated construction techniques in Canadian perspectives.

## 2 METHODOLOGY

Interviews and surveys were conducted to achieve the objectives of this study. The interviews were carried out with construction professionals in different areas of the residential construction industry. Three interviews were conducted with a custom home builder, a general contractor who primarily manages renovation projects, and a construction manager who has substantial experience with large-scale projects such as residential sub-divisions. Furthermore, the surveys were run by canvassing on several construction projects and handing out questionnaire to the participants in person, via social media survey collection tools, and by using survey monkey.

### 2.1 Interviews

The first interview participant, Kamran Samimi, is a civil engineer by background and has been working in MKS Enterprises Ltd as a construction manager on residential construction projects ranging from custom homes to mid-rise apartment buildings for the last 35 years. Mr. Samimi was selected because of his significant experience with small-scale as well as large-scale projects. His lengthy experience in the construction sector is of great value to this study because of his knowledge on past and current construction methods. Mr. Samimi was interviewed on January 18th, 2019 at his residence. The interview was recorded after taking his permission.

The second interview participant was John Sklavanous. Mr. Sklavanous has been running his own renovation/construction company, Mercer Building Services, for the last 10 years. He is an architectural technologist and a skilled tradesman in flooring, which he was taught by his uncle. After starting his own company, which specializes in renovation construction projects, he has been able to expand his company offerings to include design/build solutions for his clients. By offering both the design and build aspects of residential construction, he is able to deliver turn-key projects to his clients. Mr. Sklavanous typically advises his clients on finishes as well as the architectural side of a new/renovation construction project. In this study, Mr. Sklavanous was selected as an interviewee with the hope that he is able to give significant insight into the cost of a renovation project and the use of prefabricated construction components in the renovation construction sector. Mr. Sklavanous was interviewed by way of email correspondence.

For the last interview, Wayne Dempsey was selected because he currently has significant exposure to residential sub-division projects. Mr. Dempsey is currently employed by Habitat for Humanity as a construction manager. Many of Habitat's construction projects include the construction of residential sub-divisions. Therefore, Mr. Dempsey was chosen as an interviewee in the hope of discovering prefabricated construction methods, which are presently being used in residential construction projects. The interview with Mr. Dempsey was conducted in person on March 14th, 2019. The set of questions developed for the interviews is given in Table 1.

Table 1: Interview questions

| No. | Question | No. | Question |
|---|---|---|---|
| 1. | What is your company objective? | 2. | What is your position at the company? |
| 3. | What types of project is your company involved in? | 4. | How long does your company take to deliver each project? |
| 5. | How many workers are present on site for each project? | 6. | How much time have you been able to save using prefabricated construction methods? |
| 7. | What is the cost range of final product (per $ft^2$) for conventional construction methods? | 8. | What types of risk are there in prefabricated construction methods? |
| 9. | Which methods of prefabrication does your company use? | 10. | Can you tell me some of the benefits of using prefabricated construction? |
| 11. | What are the disadvantages of using prefabricated construction methods in relation to your company? | 12. | What are the most common delays when using prefabricated construction methods? |

### 2.2 Surveys

In addition to the interviews, surveys were conducted for the purpose of collecting primary research data to get a broader understanding of the productivity of prefabricated construction methods. The target population for the surveys included construction managers as well as tradespeople and construction workers who have had exposure to off-site building methods. Several methods have been utilized in order to collect responses from at least 50 survey participants. Canvassing on construction sites of condominium construction projects as well as small-scale residential projects was one method of collecting responses. Another method was by way of sending out emails through survey monkey. Social

media (Facebook) was also used to collect responses. All surveys were conducted in January/February 2019. The survey questions are presented in Table 2.

Table 2: Survey questions

| Question No. | Question | Response |
|---|---|---|
| 1. | Would you say using prefabricated construction methods has decreased the overall project delivery time? | a) Strongly agree<br>b) Agree<br>c) Neither agree nor disagree<br>d) Disagree<br>e) Strongly disagree |
| 2. | What would you say are the biggest obstacles for getting prefabricated construction products delivered to a project on time? | a) Logistical issues<br>b) Access to a site<br>c) Delays in production process<br>d) Other (please specify) |
| 3. | When using prefabricated construction methods, what cost advantages are there? (4 = most important, 1 = least important) | a) Reduced labour on site<br>b) Reduction in material waste<br>c) Fewer delays caused by bad weather<br>d) A faster overall project delivery time |
| 4. | Which method of construction do you regard as safer with respect to health and safety? | a) Conventional construction method<br>b) Prefabricated construction method |
| 5. | Do you agree that there are benefits from integrating design and construction for off-site prefabrication? | a) Strongly agree<br>b) Agree<br>c) Neither agree nor disagree<br>d) Disagree<br>e) Strongly disagree |
| 6. | Which method of construction would you say improves the predictability of cost? | a) Conventional construction method<br>b) Prefabricated construction method |
| 7. | Which method would you say requires less labour (cost)? | a) Conventional construction method<br>b) Prefabricated construction method |
| 8. | At which stage have you used prefabricated construction methods? | a) Precast concrete<br>b) Prefabricated exterior wall assembly<br>c) Prefabricated interior wall assembly<br>d) Curtain wall assembly<br>e) MEP (mechanical, electrical, plumbing)<br>f) Steel assembly<br>g) None<br>h) Other (please specify) |
| 9. | During the project planning phase, who was responsible for the decision to use prefabricated construction methods? | a) Client<br>b) Architect<br>c) Engineer<br>d) Construction manager<br>e) Other (please specify) |
| 10. | In the next 12 months, how often will you plan on using prefabricated construction methods? | a) More<br>b) The same<br>c) Less<br>d) Not at all |

As with the interview questions, when designing the surveys, significant weight was given to asking about the productivity of prefabricated construction methods. Some questions were also asked regarding the benefits and risks of prefabricated construction technology in Canadian perspectives.

## 3 RESULTS AND ANALYSIS

The primary research of this study was conducted by means of interviews and surveys based on the questions given in Table 1 and Table 2, respectively. Upon analysis of the data, several findings have become evident. Prefabrication methods can have a positive impact on the cost and time of a residential construction project. Research findings also have revealed that site waste can be minimized by using prefabricated construction techniques. Furthermore, the research has uncovered not only several benefits but also some risks of using prefabricated construction methods.

### 3.1 Project Delivery Time

A number of interview and survey questions focused on the productivity at the construction site with regard to time. The first two interviewees, Kamran Samimi and John Sklavanous, have had different experiences with prefabricated construction methods. When asked "*How long does it take to complete a custom build single dwelling construction project?"*, both respondents' answers were quite similar. Kamran Samimi said, *"We usually take around 8 months to deliver a project"* and Mr. Sklavanous responded with *"It depends on the project type and complexity. For example, to build a house we usually need from 7 to 12 months. General renovation of a house can take from 2 to 9 weeks."* Mr. Dempsey, who is currently managing the construction of several townhomes explained that *"It takes about 3 to 4 weeks per townhouse unit."* The interviewees were also asked "*How much time have you been able to save using prefabricated construction methods?"* Mr. Samimi responded by answering that *"Depending on what the scope is of the project, we can save anywhere from 4 to 8 weeks."* Moreover, during surveys, the respondents were asked *"Would you say using prefabricated construction methods has decreased the overall project delivery time?"* The respondents were given the choices of answers ranging from '*Strongly agree'* to '*Strongly disagree'.* They overwhelmingly answered in the '*Strongly agree'* and '*Agree'* choices, as evident from Figure 1. The survey participants were also asked "*What would you say are the biggest obstacles for getting prefabricated building products delivered to a project on time?*" to identify the factors, which affect the productivity of construction projects. The possible answer choices for this question were, '*Logistical issues*', '*Access to a site*', '*Delays in the construction process*', and '*Other*'. The most commonly selected answer was '*Access to a site*' followed by '*Logistical issues*', as can be seen from Figure 2.

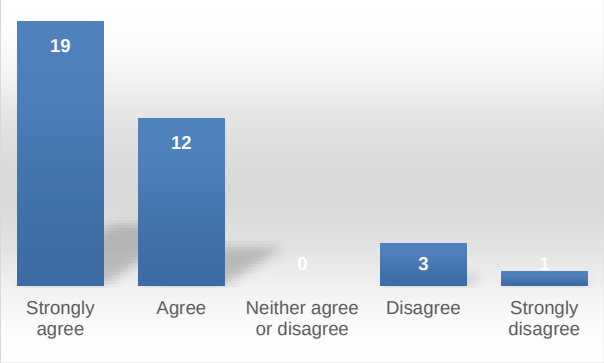


Figure 1: Survey results whether prefabricated construction methods decrease the overall project delivery time

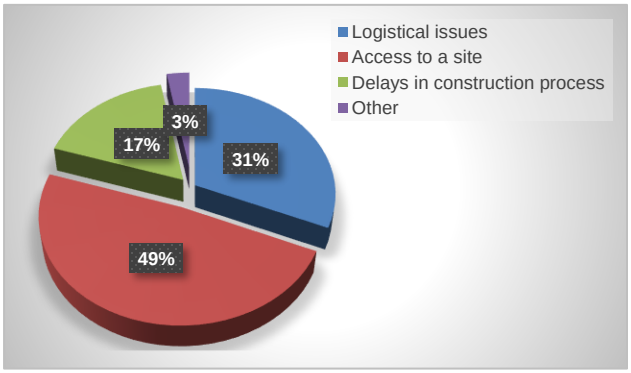


Figure 2: Survey results regarding obstacles for getting prefabricated building products delivered to a project on time

In terms of the productivity with regard to cost and time on the construction site, there are data which confirm that prefabricated construction methods have a positive effect. Mr. Samimi and Mr. Sklavanous indicated that their average project delivery time is around 10 months. On the other hand, Mr. Dempsey's projects are completed much faster. In the interview, he mentioned that stacked townhouses take four

weeks to be completed while regular townhouses can become ready in 3 weeks. This is mainly due to the reason that Mr. Dempsey's projects involve building multiple units of the exact same dimensions, for which he can use the identical prefabricated wall components. When comparing the time cited by the interviewees to the time cited by Northeast Country Homes (2012), a full prefabricated home manufacturer, it becomes evident that there are lots of potential of prefabricated construction methods, even for single dwelling residential projects (Table 3). This finding is corroborated by the response for a survey question "*Would you say using prefabricated construction methods has decreased the overall project delivery time"?* The survey respondents answered predominantly with '*Strongly agree*' or '*Agree*', as can be seen in Figure 1. The interview and survey results of this study with respect to construction time were consistent with the findings of previous studies. Navaratnam et al. (2019) mentioned that prefabricated construction methods can decrease the construction time by about 40% compared to conventional construction methods.

Table 3. Project duration by company

| Company/type of Construction | Minimum duration of project | Maximum duration of project | Average duration of project |
|---|---|---|---|
| MKS Enterprises Ltd (Custom home builder) | 8 months | 12 months | 10 months |
| Mercer Building Services (Renovations) | 7 months | 12 months | 9.5 months |
| Habitat for Humanity (Townhouse builder) | 3 weeks | 4 weeks | 3.5 weeks |
| Northeast Country Homes (Prefabrication home manufacturer) | 6 weeks | 8 weeks | 7 weeks |

Upon examination of the primary and secondary research data on project delivery time, the data show that prefabricated construction projects take less time to complete. Out of all interview participants, Mr. Dempsey's project delivery time is the shortest, coming out at around 3 to 4 weeks. His company finishes each unit faster than a home manufacturing company, which takes around 6 to 8 weeks to deliver a full prefabricated home. In comparison to the companies of the other two interview participants (Samimi and Sklavanous), the companies like Northeast Country Homes and Habitat for Humanity can take better advantage of prefabricated construction methods due to being able to use the identical prefabricated components multiple times. The survey respondents who worked mostly on large-scale projects such as condominium developments also strongly agreed with the statement that prefabricated construction methods have decreased their overall project delivery time. Furthermore, Mr. Samimi explained that a decrease in project delivery time results in significant cost savings as well. This is true for his business, because a decrease in project delivery time means that he is spending less money on servicing his mortgage loan interest. In addition, he becomes capable of taking more construction projects per year. Indeed, Chiu (2012) found based on his analysis that the greatest strength of prefabricated construction lies in its time saving along with reduced cost.

### 3.2 Project Cost

The overall cost of the project is another factor along with time that plays a significant role on the productivity of a construction project. In order to accurately assess if there is an increase in productivity for using prefabricated construction methods, the primary research of this study also focused on the cost of conventional construction projects. In this regard, two interviewees have provided insights by answering the following question "*What is the cost range of final product (per ft$^2$) for conventional construction methods?*" Mr. Samimi responded by saying *"New builds typically cost around 250 per ft$^2$"* and Mr. Sklavanous answered with *"Cost of additions are starting from $150 per ft$^2$ and the cost of new house would start from $120 per ft$^2$."* One of the main factors to take into consideration, when trying to reduce the project cost, is the cost of labour. The overall project cost goes down significantly if the labour cost can be reduced. During the surveys, the participants were asked whether labour cost is cheaper with '*Prefabricated construction method*' or '*Conventional construction method*'. The third choice for this

question was '*Equal*'. Most survey respondents selected '*Prefabricated construction method*' as their answer, as can be seen from Figure 3.

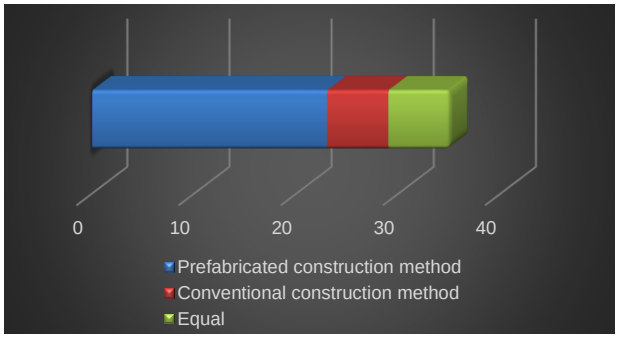


Figure 3: Survey results for the labour cost of prefabricated and conventional construction methods

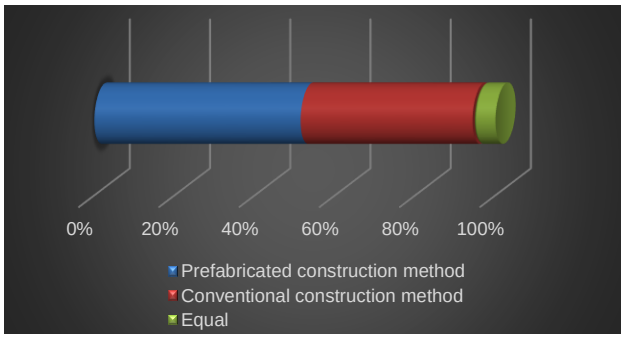


Figure 4: Survey results for the cost predictability of prefabricated and conventional construction methods

The feasibility of a construction project is usually determined beforehand, via the establishment of a construction budget. The more accurately construction costs are determined before the start of the project, the smoother the construction process will be. The success of any construction project largely depends on accurate budgets, which are determined in the project planning stage. Therefore, when designing the survey, a question on the predictability of costs was also incorporated. The results are presented in Figure 4. Most survey participants answered that '*Prefabricated method*' improved the predictability of cost.

The survey participants were also asked "*When using prefabricated construction methods, what cost advantages are there*?" to examine the factors that greatly influence the cost of prefabricated construction projects. They were given four choices: '*Reduced labour on site*', '*Reduction in waste produced*', '*Fewer delays caused by bad weather*', and '*Faster project delivery time'*. The survey participants were then asked to rank the choices from '*Most important*' to '*Most unimportant*'. As shown in Figure 5, the survey respondents answered that prefabrication allows for a '*Faster project delivery time*', thereby reducing the overall project cost.

The interview with Mr. Sklavanous proved to be helpful in terms of understanding the detailed cost breakdown of a conventional construction project and also the productivity of using prefabricated construction methods. It had been anticipated that more prefabricated construction components could be used in the renovation and custom home construction projects. The primary research uncovered that this is always the case for Mercer Building Services. Mr. Sklavanous cited a figure of $165/ft$^2$ for the cost of a 2$^{nd}$ story addition. Even higher is Mr. Samimi's average cost to complete a custom home. He answered that *"New builds typically cost around 250/ft$^2$"* when he was asked "*What is the cost range of final product (per ft$^2$) for conventional construction methods?"* These primary research cost findings justify the cost-effectiveness of prefabricated construction methods when compared with the secondary research cost data. Northeast Country Homes (2012) reported that the construction costs of prefabricated homes range from $75/ft$^2$ to $115/ft$^2$. This figure is significantly lower than what John Sklavanous provided during his interview. Table 4 outlines the differences of cost per ft$^2$ for all three companies. The project costs of both, the building company and the renovation company, are significantly higher than that of the prefabrication home manufacturer. The data show that the company which fully utilizes prefabrication construction techniques for residential dwelling have a lower cost per ft$^2$. In Table 4, the cost per ft$^2$ is 37% higher for Mercer Building Services, and 189% higher for MKS Enterprises Ltd compared to Northeast Country Homes. This represents a significant increase in construction costs for the companies which use partially prefabricated construction components. It also indicates that the construction costs will be even much higher for conventional construction methods. Overall, these data show that prefabricated construction methods bring significant cost savings. One of the main contributing factors for cost savings is the reduced number of labourers, which decreases the total labour cost by about 25% compared to conventional construction methods (Navaratnam et al. 2019).

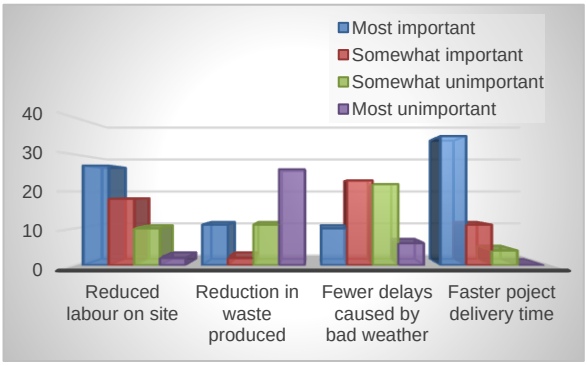


Figure 5: Survey results for the cost advantages of prefabricated construction methods

Table 4. Project unit cost by company

| Company/Type of Construction | Minimum cost (per $ft^2$) | Maximum cost (per $ft^2$) | Average cost (per $ft^2$) |
|---|---|---|---|
| MKS Enterprises Ltd (Custom home builder) | $250 | $300 | $275 |
| Mercer Building Services (Renovations) | $110 | $150 | $130 |
| Northeast Country Homes (Prefabricated home manufacturer) | $75 | $115 | $95 |

The cost advantages of prefabricated construction methods were also revealed from the results of surveys. The survey respondents were asked "*When using prefabricated construction methods, what cost advantages are there?"* The faster project delivery time of prefabricated construction methods was consistently rated as more important when it came to explain how cost advantages are achieved. Furthermore, the secondary research suggests that the primary research findings from surveys and interviews are acceptable. Bernstein et al. (2011) cited in a smart market report that 65% of the users of prefabricated construction methods stated having a positive impact on the project budgets. Chiu (2012) also found that the greatest strength of prefabricated housing lies in its substantial cost savings.

### 3.3 Benefits and Risks of Prefabricated Construction Methods

Upon examination of the productivity of prefabricated versus conventional construction methods, the research uncovered many benefits as well as risks with prefabrication methods. Both Mr. Samimi and Mr. Sklavanous described similar benefits, such as the reduced number of labourers who are present on construction site and the reduction in site waste. When Mr. Samimi was asked about some other benefits of using prefabricated construction methods, he said that "*…site waste can be reduced significantly by using prefabricated construction.*" This is consistent with the secondary research findings. Bernstein et al. (2011) found from their smart market survey that 77% of the users of prefabricated construction methods reported a reduction in construction site waste up to 44%. Moreover, Mr. Samimi said that less workers on construction site reduce the chances of labourers becoming injured. This is a significant benefit for construction companies in the context of liability. On the other hand, John Sklavanous' response on the benefits of using prefabricated construction methods was "*...Minimization or total elimination of on-site wet trades as elements are pre-formed and pre-applied in the factory setting in regard to concrete construction for example.*" In surveys, the participants were also asked "*Which method do you regard as being safer?"* Almost all participants considered prefabricated construction as being safer.

Although many benefits can be achieved by using prefabricated construction modules, there are also certain risks and disadvantages which need to be taken into consideration when deciding which construction methods should be used. Both Mr. Sklavanous and Mr. Samimi were asked about this in the interview. John Sklavanous spoke about some of the disadvantages when he answered *"There can be a lot of risks associated with prefabrication in comparison to the traditional construction methods. This is because the majority of the large building elements are constructed off-site, a huge amount of trust is given to the manufacturer to produce exactly what is needed. Therefore, even the tiniest of errors can put the entire structure in danger."* Moreover, Mr. Samimi stated that some of the disadvantages of prefabricated construction methods may result in delays in construction projects. He explained that his profitability is affected negatively by incurring delays on the construction site mainly due to the shortage of skilled labourers, product misfits, and changed orders. He elaborated "*Some of the risks are that changed orders can't be satisfied. Also, when prefabricated construction components arrive on site and they don't fit there could be huge time delays."* Both Mr. Sklavanous and Mr. Samimi expressed the same worry about building components which may not fit and have to be sent back. Not only does sending back faulty or damaged building components cause time loss, it also increases the overall cost due to the increased

delivery cost, which could be significantly higher depending on the size of building components and distance of the prefabrication facility. These findings are corroborated by Rippon (2011) who stated "*When construction of prefabricated homes is complete, the manufacturers usually use a drop deck trailer (low bed trailers used for oversized loads) to deliver the elements (modules) to the site. The drop decks are usually 50'-60' long."* Carrying the oversized loads (building modules) increases the cost and effort for transportation. It will be further increased for changed orders. The damage to the prefabricated elements can also occur during transportation (Wevill 2017). In the surveys conducted for the purpose of primary research, the respondents also expressed that logistics is a factor when considering using prefabricated building components. In surveys, the participants were asked "*What would you say are the biggest obstacles for getting prefabricated building products delivered to a project on time?"* Out of four possible choices, the respondents cited '*Logistical issues'* as the second most observed obstacle after *'Access to a site'* (Figure 2).

### 3.4 Applications of Prefabricated Construction Methods

All three interviewees were asked the following question "*Which methods of prefabrication does your company use?"* Kamran Samimi elaborated on this with the following answer *"We use prefabrication methods on different projects. For example, all of our trusses are assembled off-site. On some projects we also use exterior wall components."* Mr. Dempsey had a similar answer *"We incorporate prefabrication during the framing stage."* On the other hand, John Sklavanous answered "*The most commonly used form of prefabrication building we use is prefab concrete and steel sections in structures where one particular building element is repeated a number of times."* In order to understand at which stages of the construction process, prefabricated construction methods are mostly used or most useful, the survey participants were asked "*At which stage have you used prefabricated construction methods?"* The respondents were given the choices of '*Precast concrete'*, '*Prefabricated exterior wall assembly*', '*Prefabricated interior wall assembly*', '*Curtain wall assembly*', '*MEP*', '*Steel assembly*', '*None*', and '*Other*'. As shown in Figure 6, '*MEP*' and '*Precast concrete*' were the top answers given by the survey respondents.

The data collected from primary and secondary research revealed that prefabricated construction is used in both custom home and renovation construction sectors. The most common prefabricated method used in residential wood frame construction involves the use of wall components. All interview participants confirmed that they use some sorts of prefabrication in the framing stage. *"We incorporate prefabrication during the framing stage"* said Mr. Dempsey. However, the surveys handed out to the workers on large-scale condominium projects exhibited a different result. The workers were asked "*At which stage have you incorporated prefabricated construction methods*"? The top answer selected was *'MEP'* closely followed by '*Precast concrete*'. As revealed in the secondary research, Bernstein et al. (2011) also found out through one of their surveys that the respondents used prefabricated construction techniques mostly for exterior walls and MEP systems.

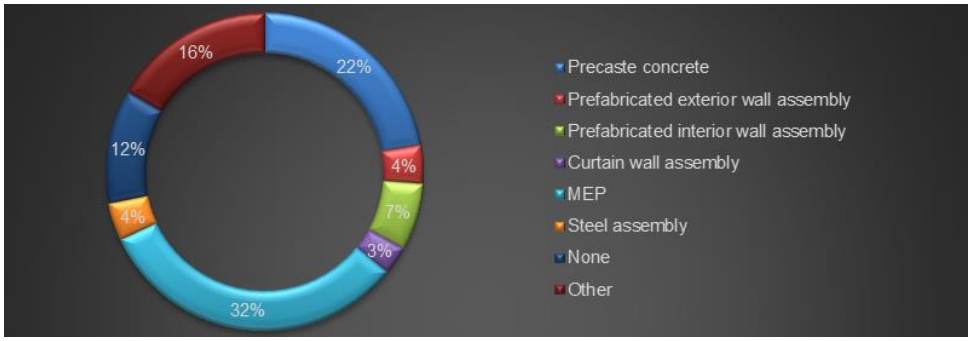


Figure 6: Survey results regarding the applications of prefabricated construction methods

Upon further analysis of the collected data, it is evident that larger firms benefit more from prefabricated construction methods due to cost savings from the repeated use of a specific building component a number of times, and therefore they have a wider degree of adoption. For example, Mr. Dempsey, who

works on larger multiplex projects, said that he always uses prefabricated wall components, whereas Mr. Samimi and Mr. Sklavanous make less use of prefabrication methods. Bernstein et al. (2011) had a similar finding from one of their surveys. Considering the size of the firm measured by revenue, they organized the survey respondents, who said that their firm uses some forms of prefabrication. The results indicated that the companies whose revenue is greater than $5 million and who use some forms of prefabrication represent almost 50% of all firms surveyed.

## 4 CONCLUSIONS

The following conclusions are drawn based on the present study:

a) Prefabricated construction methods positively influence the productivity of a construction project by reducing its cost and delivery time. Reduced labour has been identified as the second most important cost advantage after faster project delivery time.
b) Construction site waste can be reduced significantly by using prefabricated construction methods, thus leading to a lower environmental load.
c) In Canada, prefabricated construction methods are used in making trusses, exterior wall components, framing elements (beams and columns), and MEP systems.
d) Large-scale projects tend to benefit more from prefabricated construction techniques compared to small-scale projects due to the repeated use of identical building modules.
e) There are risks associated with prefabricated construction methods, particularly with respect to shortage of skilled labourers, product misfits, changed orders, oversizing, and logistical issues.

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