Living, uninterrupted: the positive potential of low impact construction

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Abstract
There is a certain level of chaos and disruption associated with the construction process. When construction becomes associated with infill urban development, it has additional negative realities as it impacts the ability of those living and working around the construction site to live a normal life, often for a significant length of time. How can the choices we make in terms of structural systems and construction methods serve to lessen that impact? This paper focuses on aspects of the construction process that pertain to choices in structural systems (mass timber, steel and reinforced/precast concrete) to create a practical (qualitative) guide towards lessening their social and environmental impact in an urban setting. Lessening the impact of construction also feeds naturally into existing objectives in sustainable design assessment tools which look for waste reduction, minimization of light pollution and the containment of processes on site.

Keywords Construction · Pre-fabrication · Sustainability

Introduction

The conference theme asks, “How are structurally focused architectural design choices positioned to make a difference in the urban perspective when considering social, economic and environmental challenges in 2022?”

Structurally there are choices to be made when selecting the systems with which we build urban structures, be they buildings or infrastructure such as bridge elements. Beyond typical questions of strength and durability, our structural choices impact the ability of others to live life uninterrupted. Construction has a tendency towards a negative impact on the area surrounding the site, be that from access issues related to at-grade conditions, or in general as the result of debris or noise generated by the construction processes themselves. Thought can be given when looking at systems selection towards the minimization of the negative impact of the construction processes. This tends to be more of an issue in dense residential neighborhoods – exacerbated by COVID-19 work from home mandates – where construction noise and dust is experienced for much longer periods of time. Even post COVID we are likely to see an increase in the number of people continuing to work more from home and so continuing to be impacted by these issues. Where many urban residences tended to be vacant during daytime hours as people were largely “away at work”, the rise in the use of the home office has exacerbated the level of conflict. Likewise for those working in office towers, the construction of residential towers is disruptive.

What is low impact construction?

This paper provides a comparative overview of mass timber, structural steel and reinforced/precast concrete systems as pertains to their respective abilities to minimize urban interference as a result of the construction process. Construction impact is a relative term. To identify lower impact methods we begin by understanding that high impact construction might be characterized by:

- length of time to complete
- high levels of noise at varying hours of the day/night
- high amounts of dust and debris
- light pollution as the result of night construction
- traffic generated by vehicle access
- lane closures to provide site access
- loss of on-street neighborhood parking
- high risk erection methods that endanger workers

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Impact also arises related to the choice of wet versus dry construction processes, thereby focusing on the benefits of prefabrication as a direct means to limit the amount of work done on site.

There is not equal choice when evaluating mass timber versus steel versus concrete systems for use in taller buildings. Questions of building code and regional preferences will dominate the viability of structural systems. At present mass timber is seeing a rise in popularity, but it is widely limited by height as driven by issues of fire resistance. There are also regions of the world where the material is simply not available. Residential and commercial buildings tend to choose different structural systems, largely for the varied needs of the mechanical, electrical and plumbing equipment.

Where it is not the responsibility of the architect to manage the construction process, it is reasonable to expect an understanding of the impact of the process on the site, neighboring areas and workers and attempt to design to minimize this impact. It is the intent to provide a practical guideline for thoughtful decision making while appreciating that the assessment is complex.

Mixed use urban neighborhoods

One of the primary intentions of modern zoning laws was to separate conflicting building uses based on issues of noise and waste generation [1]. Access to automobiles saw the rapid growth and expansion of suburban living post World War II, particularly in North America, with downtown areas dedicated to office buildings, the majority of high rise residential neighborhoods segregated by zoning and noxious industries separated from both. We have seen a tendency over the last few decades to move away from a distinct zoning separation of residential and commercial uses in our downtown or central business district type areas. Lessons taught us that downtown areas were safer when populated 24/7. Urban areas could be more vital, and with many people tending away from car ownership, walkable, mixed-use downtown areas were preferred. [2, 3]. Even skyscrapers are tending towards mixed use (residential, office, hotel) over single use for financial motives and aspects of better livability (CTBUH data collection, ongoing).

Many downtown neighborhoods are undergoing major renewal efforts, and the current trend is towards residential and mixed use infill, with higher density tower projects replacing badly aged low rise buildings to make more efficient, sustainably motivated use of the urban core, discourage commuting and limit sprawl to preserve farmland and natural habitat. Renewal brings with it large amounts of construction, and associated disruptive adjacency issues between active sites and fully occupied buildings. Normal living is greatly interrupted for occupants. Referencing the ideas of Jane Jacobs and Jan Gehl, and the need for pedestrian friendly spaces for interaction, sustained construction not only takes many of these spaces away, but the industrial nature of construction activities also make adjacent areas less viable for interaction as well as compromising safety.

Site area, staging and traffic

Structural materials and systems have differing requirements for site access, delivery, staging and site preparation. Are certain systems more easily handled in confined situations? If vehicular access to urban sites is restricted by truck length (turning radii and clearances) can members be shipped in shorter lengths and spliced on site? (Fig. 1).

Tight site constraints are fairly typical in the urban environment, regardless of region or place, practically impacting access to the site for demolition, excavation and construction. Urban building footprints tend towards minimal setbacks and high coverage. Over time we have seen the widening of roadways to accommodate multiple lanes of vehicles leading to a corresponding erosion of sidewalk and front yard spaces and setbacks. This tends to result in a lack of staging area for construction and often requires the assumption of a portion of the fronting and adjacent street(s) for staging and deliveries. Construction frontages in the accommodation of waiting trucks for delivery, remove street parking for the duration of the project.

Fig. 1 Street closures are common during construction to permit the delivery and installation of oversized elements as well as for the moving of construction aids such as flying forms. It is essential to avoid pedestrian interference during these times as a factor of safety.
normally already in short supply in downtown areas. This also impacts the economy of local businesses.

Infill construction necessarily brings heavy truck traffic into neighborhoods that would not normally need to accommodate these types of vehicles. The engine noise from running trucks may be somewhat covered by the general level of white noise in the city, but reversing signals are readily apparent. The inherently quieter the neighborhood, the more offensive the noise from equipment.

“Heavy trucks have been involved in several fatal collisions in recent years. A Toronto Star (newspaper) analysis of 15 years’ worth of data from 2006 to 2020 shows dump or cement trucks were involved in 11 per cent of all pedestrian deaths and more than a quarter of all cyclist deaths [4].”

The crane location or locations for the site will need coordination. The delivery access needs to be coordinated with the location of the crane that will be used to offload materials. Given the numbers of tower crane failures it is preferable to also study the location and swing of the arm that it not carry goods over adjacent residential properties.

The staging area for a project, its size and location, will feed rather directly into the potential overflow of the project into the surrounding neighborhood and tends to be site and not material dependent. Although some tightening up of delivery and laydown of structural members is possible, it is practically limited. Most municipalities prefer a gated site with all offloading of materials happening within the legal site boundaries. Most dense urban sites will not be able to easily comply, and so it has become normal to assume a site boundary that extends over the pedestrian sidewalk and for the hoarding to provide pedestrians with a safely enclosed walkway. If this is still insufficient to provide enough space within the site boundaries, then adjacent roadways will require permitted access, thereby further extending the site boundaries (for payment to the municipality) and impeding the natural flow of traffic and pedestrians in the area. The extended size of this area requirement will feed into the delivery of structural materials as these have the largest size impact.

Hording and pedestrian protection can be designed to be more aesthetically pleasing and even interactive. As it will be in place for a significant time, viewing windows into the site can enhance the experience. If windows included at varying heights, even children can watch the construction. These are normally fabricated from timber and plywood, the flat surfaces of which could be used for temporary urban artworks. Project information can also be included, even with an educational aspect. Although normally not part of the architectural project, there is an opportunity for intervention to improve this very public face of the construction site (Fig. 2).

**Shipping limits and component size**

Most major construction materials are delivered to site by transport trucks. These need to be accommodated for offloading of materials. From the perspective of maximizing the length of components (steel beams, CLT slabs, glulam or precast elements) there will be turning radius implications when accessing a site in a dense location. From a design perspective, when thinking about length, this can impact bay size, column spacing and ultimately material choices.

**Mass timber** CLT slabs are designed to maximum span based on the variation in the numbers of ply thickness of the slab with 7-ply supporting the greatest span length. Generally long span CLT (also used to fabricate support cores in lieu of reinforce concrete) is manufactured at a width of 3.0 m with length ranging from 16 to 18 m. A standard flatbed trailer can accommodate 16.0 m in length and so if larger spans are desired, non-standard shipping will be required. Standard flatbed width is 2.6 m as this fits within most normal traffic lanes, and so to accommodate standard CLT panels by width may require special permits for wide load. CLT is not able to be spliced to extend its length. A shorter length would infer changes to the support system, frequency of beams and bay sizing all of which may

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**Fig. 2** The addition to the Art Gallery of Ontario, Toronto, Canada by Frank Gehry had very tight site conditions. The boundaries required assuming one lane of traffic to provide at best the ability to park and offload a single truck. Pedestrians were forced to walk on the sidewalk on the opposite side of the street. The crane operator did not have a clear view of the work.
be required in order to shorten shipping lengths to suit the travel path.

*Structural steel* is able to be spliced on site if the desired span lengths of assemblies exceed the normal limits of a standard flatbed truck. If splicing is required then consideration needs to be made for the availability of lay down area on site to complete this process prior to lifting, or mid-air support/shoring if it is to be completed at height. On occasion for extremely oversized elements such as trusses, articulating trucks can be used where by the cab and front support are distinct from the rear support for the member, which is driven via computer link. In this way oversized elements may be more easily moved around tight corners, although advance planning is required for assurance. These types of transport will normally require a police escort for the full driving route (Fig. 3).

*Reinforced concrete* as a wet process will not have sized based shipping limits. However for large or continuous pours concrete trucks will need space for queuing and this will disrupt traffic for extended periods. For projects considering the use of flying forms, the impact of the removal and replacement of the forms often requires access to the airspace over adjacent streets. This disrupts the flow of traffic and pedestrians across the frontage for the duration of the activity.

*Precast concrete* will have similar limitations to mass timber as it is also delivered as a prefabricated unit and is not spliced on site. Length limits will again inform bay spacing on the project.

*Inclement weather* will impact the delivery of materials equally as trucks tend to track mud onto entrance walkways and adjacent roads. Some environmental regulations may require that this be limited or remediated, but this varies worldwide. Mud tracked across pedestrian walkways can be lessened if efforts are made. Projects working towards LEED™ ratings will have mandatory requirements in place to limit the tracking of mud from the site as runoff will impact adjacent sewers. This is addressed in the Sustainable Sites Prerequisite: Construction Activity Pollution Prevention, which addresses erosion, waterway sedimentation and airborne dust [5].

### Speed of construction

Naturally the faster a project can be completed, the less environmental and societal disruption. Under this topic we need to separate the speed of construction of the structure from the exterior envelope and interior finishing systems as they are independent decisions. A more holistic adoption of prefabrication will have the benefit of overall time shortening (see 8-Prefabrication). When it comes to framed systems such as mass timber and steel, the number of individual elements to handle as well as the number and types of site connections will factor heavily into the time to complete. Maximizing component size and minimizing the number of lifts will reduce crane time.

*Steel, reinforced concrete and mass timber systems* proceed at distinctly inherent paces, which are also climate and weather dependent. The pace of construction can be negatively impacted by rain and snow in particular, requiring extra protection to prevent damage to materials or a complete delay due to freezing temperatures. The seasonal timing of a project as well as its geographic location may suggest different material choices to avert the excessive extension of the project timeline and its associated impact on the area.

*Reinforced concrete* is the most temperature dependent of the primary structural materials. It cannot proceed in freezing temperatures, requiring the installation of space heaters and a temporary enclosure system to retain the heat. Excessive heat will also disrupt the curing process and require coverings to prevent evaporation. Some of this can be mitigated by looking at the construction timeline to ensure that the bulk of the work takes place in more suitable weather.

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**Fig. 3** The Addition to the Royal Ontario Museum in Toronto Canada by Studio Libeskind required significant laydown area for the pre-assembly of the odd shaped steel diagrid elements. Their shape negated shipping pre-assembled. Where much area was available during the early phase of construction, this eroded as the building grew. The need for this space informed aspects of the construction staging.
The choice of material for the core will tend to govern the overall timeline for the erection of the structure in composite systems. If reinforced concrete is used, as it tends to be for tall buildings regardless of the material chosen for the floors and columns, it will slow down the overall process as concrete takes 28 days to reach its fully cured strength. As concrete placement is a wet process, it cannot benefit from prefabrication, and so also has the added burden of the construction and moving of the formwork, and often addition and removal of temporary shoring (Fig. 4).

Mass Timber systems that consist of glulam columns and CLT slabs can ordinarily be completed faster than other systems. This is largely due to the prefabrication of the materials prior to arrival at the site, the larger size of the components, and the use of specialized connection procedures. The Wood Innovation and Design Centre in Prince George, British Columbia, Canada, by Michael Green Architecture was completed in 2014. The 6 story commercial building was fully complete within a 16 month design build process. Critical to this timeline was the use of a CLT slab core versus reinforced concrete. Additionally a prefabricated system of exterior cladding was also employed, greatly reducing the time to complete.

Structural steel systems will typically take longer than mass timber to complete the column, beam and floor framing as the connection completion time for standard bolted and welded steel connections takes longer than for the Megant or Ricon type fasteners used in mass timber systems. The advantage of using a standardized fastening system lies in the consistency of the actions of the workers. Variations between connections tend to slow down the process. The steel floor system will require the installation of beams and joists to support the steel decking. As these components are more numerous to construct equal floor area, versus CLT or hollow core precast slabs, this increases installation time and crane time.

Both mass timber and structural steel will be impacted by the time to add the reinforced concrete that is used for the composite floor system. Both systems require the installation of metal connectors to bond the concrete to the floor system. This is a very manual process adding significant time to the build. Mass timber buildings will often require the added mass provided by the concrete floor to control vibrations as the overall system is quite light and can be difficult to provide movement damping. This also means that these sites will need to queue concrete trucks for the delivery of this material.

Reinforced concrete buildings will typically take longer to complete the structural framing due to the added time for the installation and removal of formwork as well as curing time. There are building types, such as residential towers, for which this structural system has become standard and so to make an alternate choice for terms of speed may not possible due to local customs, material availability and labor. A more regularized floor plan and the use of flying forms can be used to accelerate the process as the building of the formwork adds significantly to the time to complete.

Precast concrete structural systems are not globally common for the construction of tower type infill projects. Precast concrete hollow slab flooring systems have similar advantages to CLT slab systems in terms of speed of erection over stick built steel systems and can often be seen used in conjunction with steel frame buildings resulting in an overall shortening of construction time. In certain countries such as Japan, precast concrete systems are becoming standardized in the construction of residential towers as they provide a good level of mass over steel systems (which still tend to be more common for office construction there) and have added speed over standard reinforced concrete methods, though admittedly still employ significant amounts of wet placed concrete to connect members and top the slabs. They are being designed for seismic resistance. As these tend to be used on towers in excess of 20 stories, the dimensions of the columns tend to be much larger than would be found in a traditional reinforced concrete apartment tower using shear wall type construction (Fig. 5).

The reality of excessive column sizes as impacting the plan could also be seen to feed into aspects of livability in the associated residential spaces. This is a trait shared by the new precast concrete residential structural system.
being used in Japan and the extremely tall mass timber towers. Although not a construction related issue, the material selection does impact the use of space quite directly.

**Noise, dust and light pollution**

The construction day in most urban environments begins at 7am and tends to wind down before late afternoon rush hour traffic begins. Construction may be limited on the weekend when it is assumed most people would be “at home” and offended by high noise levels. The “at home” times have expanded due to work from home trends as a result of COVID-19 and so noise, dust and light pollution can be seen as more important to control on the construction site for an urban infill project than in previous times. Particularly in non-heating/cooling seasons where windows can be opened for natural ventilation, adjacent construction processes may make natural ventilation impossible. Noise makes direct interference with online meetings. Varying materials processes generate different types and levels of site debris. Which systems and processes tend to result in the lowest impact in this area?

Different construction processes have varying noise levels as a natural result of the activity on the job site. Whether the beeping of the trucks reversing, the churning of the concrete truck, sawblades cutting or the hammering of bolts, all result in a disruptive state for neighboring sites, again citing work from home adding to potential conflict [6–8]. However the intensity and frequency of the noise will vary based on the type of structural system construction in progress and particular equipment being used. A louder noise of a shorter duration that happens less frequently may be less offensive than a lower level one that lasts for a longer period of time. Most construction safety associations will have rules regarding the wearing of ear protection for workers on site, and so have information for review on the relative noise levels of a wide range of equipment. Ear protection is necessary above 85 db(A). For reference a speaking voice is around 60–70 db(A).

**Mass timber** is quieter than most processes as there is little to no sawing or remedial fitting work carried out on site. Panels and columns arrive to size with cut-outs done in the shop for best finished results. The tools used to complete the connections are not as noisy or as frequently used as for other wood framing cases. Unlike light wood framing, there is no nailing which tends to generate fairly constant sharp noises. There is little to no exterior debris or dust associated with the construction process given the lack of saw use.

**Structural steel** erection will have noise associated with the installation of connections that will be exacerbated if the fit is incorrect and the steel needs to be forced into position. Welding runs 98 to 119 db(A). The installation of steel decking will also be the source of noise at around 100 to 120 db(A) (Fig. 6).

In **reinforced concrete** applications, remedial work such as grinding, sawing and chipping exhibit some of the most significant noise levels in the range of 95 to 103 db(A). This type of work creates very high dust levels and so some municipalities will require water use to dampen the dust. Some of the equipment is also gas powered, so emit noxious fumes.

**Standard light frame timber** has some of the highest ongoing noise offense as tools such as saws have a high shrill noise associated and their use is very frequent. Circular saws and hammering run about 96 db(A) and a chop saw 106 db(A). However once the project is enclosed the exterior noise levels are dramatically reduced. The take away would be to enclose the project as quickly as possible in order to contain noise and the dust associated with drywall finishing within the project, and where protective gear will naturally be worn.

*Care needs be taken in managing the debris and dust on the construction site.* The waste generated from processes that are highly prefabricated will be less than those using more traditional framed or wet methods. It is not uncommon now for authorities to require more complete protection on tall building projects to prevent the wind from blowing debris from floors as this poses a huge danger to the public. Such protection also improves the safety and environment for the workers.

*It is not uncommon for some cities to provide special permits for night construction.* The need for the closure of streets to accommodate lifts of large elements would be a
cause for such a permit. In dense urban areas it is usually not possible to close entire streets to traffic for an extended time during the day except for exceptional circumstances. It might be preferable to use night hours as the interruption to daytime traffic flow can be lessened. This results in noise and at night, the spillover light from high intensity lamps to provide for a safer work environment. Again the uses of adjacent properties may be taken into account. It is prudent to ensure that the closure is as limited as possible and so the elements to be installed are designed to be put securely into place as quickly as possible. This will mean a high level of prefabrication, maximization of the element size as often on site pre-assembly may also not be possible given constricted site conditions (Fig. 7).

**Prefabrication**

The maximization of off-site construction directly improves many aspects of the construction process feeding quite directly into a lessened impact of construction on the area. The structural system materials lend themselves to prefabrication to varying degrees. The height and size of the building will feed into this decision as certain systems, though more easily prefabricated may be deemed unsuited to buildings of increased height due to issues related to fire resistance.

Prefabrication naturally takes advantage of climate controlled shop fabrication which reduces site impact in a number of ways. Most of the fabrication processes that require specialized equipment, many of which create noise, can be done in the shop, removing the impact of the noise and dust inherent in site processes. The net benefit in the overall reduction of noise and dust/debris on site varies between the structural systems. Prefabrication and shop fabricated processes are also less weather dependent in achieving optimal results for the production of elements. However each structural system has differing requirements against the effects of weather when the elements are brought to site for erection [9].

For **erection purposes** the arrival of larger prefabricated elements has the potential to lessen the time to offload trucks. The availability of staging area and even ownership of the fleet will impact the decision to offload to the site or

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Fig. 6. (Left) Different tools and processes will result in varying noise levels on the site. When steel needs to be forcefully fit into a connection, the resulting impact is great, although normally of short duration. (Right) Although the overall form of the VIA Residence in New York City by Bjarke Ingels Architects would have been slowed due to the irregularity of the shape and required concrete formwork, the cladding was prefabricated off site and was installed in a fairly expedient fashion.

Fig. 7 Night lifts are very common for bridge type structures (Left) as traffic will need to be halted during the process and night hours are the only times where a 5 h closure might be permitted. This will require an expedient lift of completed spans if at all possible. (Right) The lifting of this 31,000 pound cast steel node required the closure of an adjacent street to permit proper crane access in a tight urban site condition. Adequate event specific lighting was required for safety reasons.
lif directly from the transport. These decisions tend to be material independent and more site and situation dependent.

*Mass Timber systems* are proving to be top rated when it comes prefabrication as the industry has tooled itself towards the maximization of prefabricated elements, leaving little to no cutting requirements on site, eliminating noise and dust. The elements arrive to site, often with the attachment mechanisms pre-installed. The CLT floors can be lifted directly from the arriving truck and up to installation on the project. There can be less tendency towards storage on site if the site area is constricted. However if it is necessary to install the fastening systems on site, then staging area will still be required.

*Concrete systems* will only feed into the prefabricated process if precast systems are employed. Site cast concrete persists in being one of the slowest moving processes due to the additional requirement for formwork and the curing requirements of the concrete – with some shoring required to be in place until the full 28 day strength is achieved. The use of a concrete topping is normal with both CLT and steel framed flooring systems. The curing time is less of an issue in these instances as the primary spanning system is providing a permanent form and so it is easier for the construction processes to work around the curing time for the topping. The overall form of the concrete system can exacerbate the need for shoring, with sloped columns being a top offender.

*Precast concrete floor and beam systems* can be installed faster than steel decking on a standard structural steel frame, however the installation of a topping is still required.

*The prefabrication of enclosure systems* – which feeds back into a lessened impact in the area of noise and dust/debris generation – can assist in shortening the construction time, reduce noise and debris, and provide an earlier enclosure of the building than bespoke systems, thereby containing noise and debris within the building and away from neighboring properties.

Construction of the mass timber structure at the University of British Columbia’s 18 story Brock Commons Tallwood House took about nine weeks, finishing two months ahead of schedule. The average speed of the mass timber erection and envelope installation was two floors per week. This included the columns and CLT floor panels, encapsulation of the wood components with gypsum board, the pouring of a concrete topping, and installation of the prefabricated envelope panels. Maximizing the prefabricated wood components led to less traffic, reduced waste and a quieter, smaller site. The project used a pair of reinforced concrete stair/elevator cores for stability, which extended the time to complete, however necessary for fire code requirements.

**Fire protection**

The ability of the structural system to meet fire protection requirements will impact the length of time to complete as well as environmental cost of the project. The nature of the protection required will vary greatly as a function of location, building use, height and local regulations. In broad terms the application of a fire protective covering to the structural system can change the base assessment of the materiality of the system itself – from being more benign to a higher environmental cost. Mass timber, steel and reinforced concrete have differing inherent natural abilities to resist catastrophic failure to due fire. If an additional material layer is required to create the fire resistance rating, this needs to be considered as part of the impact cost.

*Mass timber* relies on the development of a significant char layer during a fire event to create its protection. If the intention is to leave the mass timber exposed for aesthetic impact, the sizes of the members must be radically increased, thereby also increasing the use of material. Although timber is a renewable resource, this increase in volume also puts pressure on new growth requirements for the timber industry. If we are looking at high rise development, the cross sectional area of the columns can reach up to 1 m x 1 m, which starts to impinge on the useable space in the building when compared to comparative column dimensions for steel and reinforced concrete buildings of equal height. Alternately a multi-layer gypsum board encasement or intumescent coating can be provided. This reduces column size but also incurs a time factor for installation and the need to remediate the debris and dust from the process.

*Mass timber is assembled with steel connections.* This requires special detailing when using hidden connectors to ensure that the steel is fire protected (if the timber is exposed) and so there is additional cover required from the face of the timber at the connection to the steel, which is also recommended to have an intumescent strip surrounding as there will inevitably be an air gap at the connection providing heat access directly to the steel.

*Structural steel systems* will normally require a fire protective covering as most buildings must be protected beyond the ¼ hour natural limit of the material. The choices vary as a function of building use, risk and height. Intumescent coatings are popular as they allow for the exposed steel to be incorporated into the architecture of the space. The products range from low VOC to high VOC and site versus shop applied. If high VOC coatings are applied on site, the building must be evacuated during the application and curing time. Cementitious products are spray applied, adding time and the need to enclose the space to prevent wind drift of the material. These are not normally left exposed to the interior as their rough texture is a trap for dust and dirt, and so are normally concealed by either a gypsum board enclosure system or a suspended ceiling system. Both add again to the time and environmental cost of the project.

*Reinforced and precast concrete* are inherently fire resistant and do not require additional protection.
The majority of tall buildings will also require a fire suppression system, regardless of structural material.

**Worker safety**

Injuries and deaths as a result of construction accidents must be viewed as the ultimate interruption of life. The low impact construction site, with its emphasis on cleaner and more expedient construction processes, including prefabrication, has a natural tendency to improve the environment of construction workers. Structural systems can be chosen to reduce or eliminate excessive at height work, such as welding operations, in deference to more expedient connection systems. This will naturally need to be tuned to regional preferences and the availability of specialized labor forces and structural materials (Fig. 8).

*Mass timber* systems in their tendency towards prefabrication and bolted site connections creates very low risk for workers. Noise and dust are less of an issue.

*Structural steel* systems need to be well planned towards the fabrication of maximum sized elements in the shop, where conditions are more suited to high quality welding, with a preference for the use of bolted connections on site. There is a move towards limiting welding at height as it poses greater risk to the ironworkers, requires the erection of safe working platforms and extends project duration.

*Reinforced concrete* systems, due to their extensive requirements for the fabrication of formwork, installation of reinforcing elements:

Table 1 Overall Assessment of Material Choice and Impact

| Aspect/Material Choice      | Mass Timber | Structural Steel | Reinforced Concrete | Precast Concrete |
|-----------------------------|-------------|------------------|---------------------|------------------|
| Length of Time to Complete  | Shortest    | Mid-length       | Longest             | Mid-length       |
| Site Area, Staging          | Minimal staging and site storage if just in time delivery | Minimal staging and site storage if just in time delivery | Queuing of concrete trucks; Flying forms | Minimal staging and site storage if just in time delivery |
| Site Assembly Area Requirement | Unusual to preassemble components on site | Beneficial to pre-assemble components on site | No site area for component assembly | No site area for component assembly |
| Component Size              | Can be very large; no splicing possible | Can be very large; splicing possible | Not relevant for structure; may impact formwork | Can be very large; splicing unusual |
| Truck Traffic               | For component delivery; concrete floor toppings | For component delivery; concrete floors | For formwork delivery; queue of ready-mix trucks for duration of structural pours | For component delivery; concrete floor topping |
| Noise                       | Quiet       | Banging, metal scraping | Mostly from erection/disassembly of formwork/ shoring | Mid-range |
| Dust/Debris                 | Minimal     | Minimal          | Potentially from concrete cutting, formwork refuse | Minimal |
| Prefabrication              | Very high potential | Varies as a function of element size and design | No potential | Mid-potential based on scope of use of precast elements |
| Fire Protection             | Varies greatly by height and jurisdiction | Typically requires a protection system | Fire protection inherent | Fire protection inherent |
| Worker Safety               | Very good   | Highly dependent on amount of welding at height | Good | Good |
systems, shoring, and surface finishing operations seem to have little to offer in terms of means to improve work conditions.

**Precast concrete** systems in their predominant use of larger prefabricated elements and steel type connections can provide a safer work environment.

**Conclusion**

The act of construction impacts the day to day living of occupants surrounding the site. The longer the project takes to complete, the greater the interruption to the ability of neighbors to live normally. This is a complex problem as the ability to choose the structural material for projects will vary greatly as a function of the building type, building height, local codes, availability of labor and materials and regional preferences. The paper has provided an overview of aspects of the construction process that need to be considered that may lead to different material choices and design decisions on the project. There is no simple correct answer, but potentially ways that the impact can be lessened.

The answers to this question are necessarily qualitative. The following table provides a comparative overview of some of the aspects reviewed in the paper (Table 1).

**Declarations**

**Conflict of interest** As far as I am aware I see no conflict of interest between myself and any reviewer that might be chosen to look at this manuscript. The manuscript speaks of a range of materials in what I see as a quite even manner – and so not favoring one over the other – not catering at all to an industry sponsor or interest.

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