AIMCH

TRANSFORMING HOW WE BUILD HOMES

Advanced Industrialised Methods for the Construction of Homes (AIMCH) Report

Health and Safety Risk Profiling of MMC Systems

March 2022

mtc Manufacturing Technology Centre

L&Q

Construction Scotland Innovation Centre

Forster Group

Stewart Milne Group

Barratt Developments PLC Building Excellence Since 1958

Industrial Strategy

UKRI UK Research and Innovation

EXECUTIVE SUMMARY

The Health and Safety (H&S) MMC Risk Profiling work package was led by AIMCH partner Stewart Milne Group, with support from Limberger Associates, who are providing Project Management services to the AIMCH project. The Health and Safety Executive (HSE) provided support to AIMCH in producing this document.

The objectives of this work were to present the differing safety risks when using advanced panelised MMC systems compared with more traditionally built panelised MMC systems, i.e. comparing the use of on-site forklift and manual assembly techniques (GEN1) with more advanced timber frame MMC systems, utilising higher levels of prefabrication (GEN3) and requiring the use of a crane on-site.

Figure 9. On-site H&S risk exposure comparison: GEN1 Loose Joists vs GEN3 MMC Floor Cassettes

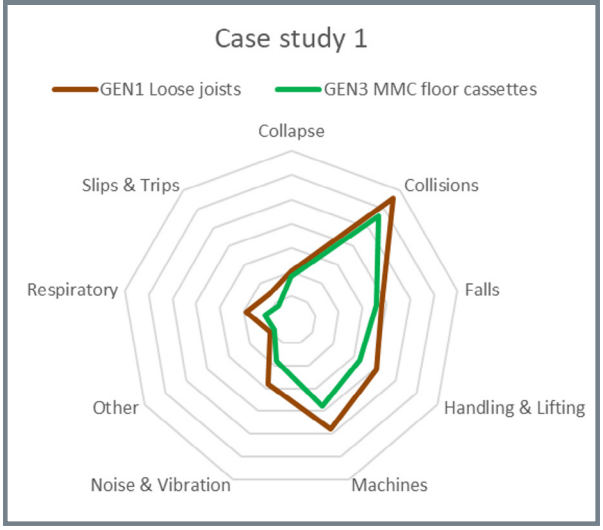
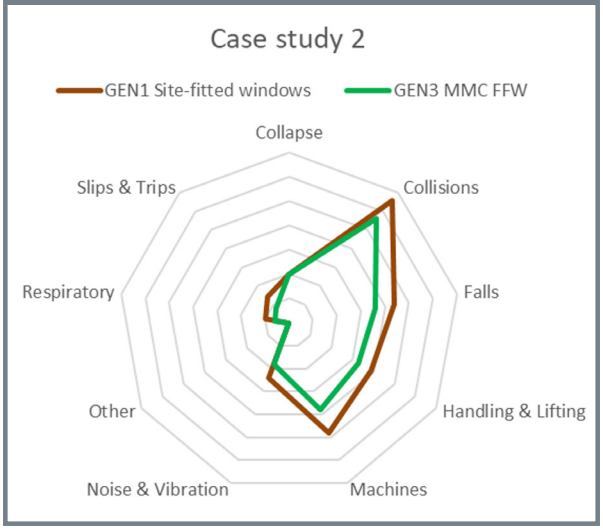


Figure 17. On-site H&S risk exposure comparison: GEN1 Site Fitted Windows vs GEN3 Factory Fitted Windows



The report concludes **20% less** H&S hazard exposure using advanced crane erect timber MMC systems

Total H&S risk exposure in risk groupings for Case Study 1 and 2 and GEN1 vs GEN3

HSE IRP grouping	CASE STUDY 1		CASE STUDY 2	
	GEN1 Loose joists	GEN3 MMC floor cassettes	GEN1 Site-fitted windows	GEN3 MMC FFW
Collapse	20	18	20	20
Collisions	66	56	66	56
Falls	38	36	44	36
Handling & Lifting	41	33	39	33
Machines	48	38	48	38
Noise & Vibration	28	18	24	18
Other	10	8	0	0
Respiratory	19	11	10	6
Slips & Trips	14	8	14	8
TOTAL RISK EXPOSURE	**284**	**226**	**265**	**215**
Reduction in on-site risk exposure: GEN1 to GEN3	**-20%**		**-19%**	

H&S risk profiling was undertaken on the following build techniques, with the GEN3 build techniques designed to increase the level of offsite prefabrication and simplify construction assembly on site compared with GEN1:

1. GEN1 forklift & loose joists vs GEN3 crane & floor cassettes
2. GEN1 forklift & site fitted windows vs GEN3 crane & pre-fitted windows

These two areas were selected to highlight the differing safety requirements and risk profiles. AIMCH partners have built several homes using both techniques to prove the case for scaling up using increasing Pre-Manufactured Value (PMV, the proportion of offsite manufactured components within overall construction cost). The ultimate focus is on building a weatherproof, insulated, and secure structural shell in one day, ideally with no scaffolding and using a pre-tiled roof. This requires the use of a crane and the following MMC solutions:

Current Advanced Panelised MMC systems:

a. Insulated closed panel MMC wall systems
b. Pre-fitted windows & doors
c. Ground erect roof systems (built prior)
d. Prefinished floor cassettes
e. Pre-loaded dry lining and stairs components

Future MMC developments:

f. Scaffold-less erect systems
g. Pre-tiled roof & lifting systems
h. Pre fitted weatherproof stairs
i. Prefabricated bathroom/en-suite pods
j. Pre-fitted external claddings

Key conclusions from the risk profiling:

1. **This report concludes that advanced MMC can reduce H&S risk exposure on-site by 20%, with a changed risk profile compared with more traditional methods –** It is concluded that GEN3 crane erect advanced MMC systems can provide a generally safer onsite working environment, although the safety risk profile differs from traditional systems. This is because many smaller, more frequent, and lower impact risks, that over time can lead to health issues, such as MSD (musculoskeletal disorders), are reduced or eliminated in GEN3. However, there is an increase in risk of very low likelihood, but high impact safety events., due to the use of a crane for heavy lifting operations. Cranes are not uncommon, but as the use of advanced MMC increases, this will become an increasing safety consideration with stringent management requirements.

2. **Some H&S risks associated with advanced MMC methods are displaced to MMC factory –** There is a transfer of some H&S risks from the construction site to the factory. Whilst this is beneficial to constructors, it is recognised that the MMC supply chain must drive safe factory operations to ensure that there is no net increase in risk for more advanced MMC-built homes. Risks can be effectively mitigated and controlled within the factory environment, where workplace safety systems are generally well managed. Many MMC suppliers are investing in safer and more productive factory techniques that eliminate manual working hazards, through introducing mechanical handling, automation, and robotic applications, as well as through standardisation of processes and components. Hence, in order that transfer of risk to the factory does not lead to an abdication of risk management, the procurers of MMC systems must ensure that effective controls are put in place so that an overall net safety gain is realised for the good of the sector.

The aim of the AIMCH partners is to deliver large numbers of high quality, functional and appealing homes, safely and at an affordable cost, to support government targets. This is achievable through the creation and exploitation of current and future industrialised housing techniques, such as panelised MMC building systems with high Pre-Manufactured Value (PMV).

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Table 1. ***Glossary of terms***

TERM	MEANING
The Project	The AIMCH project as described in the Project Application
AIMCH	Advanced Industrialised Methods of Construction for Homes
Partners	Members of the consortium who have signed the Consortium Agreement
FLT	Fork Lift Truck
GF/FF	Ground Floor/First Floor
H&S	Health & Safety
HSE	The Health and Safety Executive
IRP	Industry Risk Profile
LOLER	Lifting Operations and Lifting Equipment Regulations
MMC	Modern Methods of Construction
PMV	Pre-Manufactured Value
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations

1. INTRODUCTION AND BACKGROUND

Modern Methods of Construction (MMC) are critical to an effective industrialised housing approach. The automotive industry has shown how standardised, automated prefabrication and assembly line processes can be leveraged to derive significant business benefits, such as reducing costs, increasing productivity and improving quality and safety, which are all valued by customers.

AIMCH partners were keen to better understand the H&S risk benefits and changes associated with panelised MMC systems, as a key project output and housing industrialisation measure.

The work presented in this report was spun out from Work Package 6 and led by Stewart Milne Group, who engaged Limberger Associates, who are providing Project Management services to AIMCH. The aim of this work was to explore how MMC systems being developed and scaled up by AIMCH partners can impact on H&S risk profiles within the construction environment.

The Health and Safety Executive (HSE) provided support to AIMCH in producing this document.

Very little work has previously been carried out on the H&S impacts of MMC systems in the UK. This is an area of significant interest to stakeholders such as the HSE, housing developers and MMC suppliers, for whom workplace safety is top priority.

The Health and Safety Executive (HSE) are represented on the AIMCH Stakeholder Group. General issues regarding the impact of MMC on H&S risks were discussed with group members and this led to several workshops being held in 2021 to develop material supporting this report.

2. OVERVIEW

The following approach was developed to undertake H&S risk profiling studies of MMC systems that are being trialled by AIMCH partners:

1. Review MMC definitions
2. Identify MMC systems to be assessed
3. Develop assessment methodology
4. Carry out a subjective assessment of risk impact
5. Final report
6. Prepare an Information Paper on H&S Risk Profiling, to be available from www.aimch.co.uk

An early part of the work was to narrow down the risk profiling assessments, since it is evident that there are a wide range of safety changes when using MMC systems. Therefore, it was agreed to focus on the difference between forklift and manually assembled timber frame vs the increasingly more common, crane-erect timber frame advanced MMC systems, using more prefabricated elements. Crane-erect panelised MMC systems are favoured by AIMCH developer partners, providing a key scalable outcome from the project.

Within this approach, it was agreed to undertake desktop risk assessments of two areas of increased prefabrication, that are likely to become commonplace. These were defined in two case studies:

1. GEN3 crane erect, MMC floor cassettes vs GEN1 forklift & loose joists
2. GEN3 crane erect, factory fitted windows vs GEN1 forklift & site fitted windows

The work presented in this report delivers a conclusion on risk exposure comparisons between the two construction solutions for these two case studies. To support the risk assessments, deep dives on safety hazards and appropriate safety management processes have been described. To enable conclusions to be drawn, a risk assessment methodology was developed to enable comparative risk exposure profiles to be created. This final report will result in an information paper to be published on www.aimch.co.uk, as a thought paper on MMC safety considerations, for industry wide review and consideration.

3. MMC DEFINITIONS

As a basis for understanding, AIMCH adopted the UK government MMC definitions, developed by Cast Consultancy.

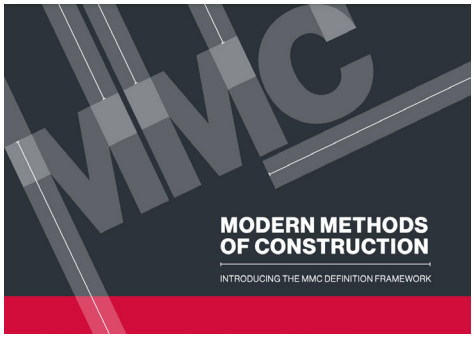
The focus of AIMCH housing industrialisation is the use and mainstream scaling up of Category 2 Panelised MMC Systems. These systems are often used in conjunction with lean construction processes (Category 7) and sub-assembly elements (Category 5), producing a hybrid set of MMC solutions, which increase Pre-Manufactured Value.

Pre-Manufactured Value is a relatively new term. It is used as a measurement of the value of offsite construction used on a project, based on a calculation method that uses a range of commercial and technical data.

PMV and MMC definitions are driving change in the housing market. All affordable housing that is funded through Homes England now requires 25% of units built using MMC and yielding a 55% PMV value.

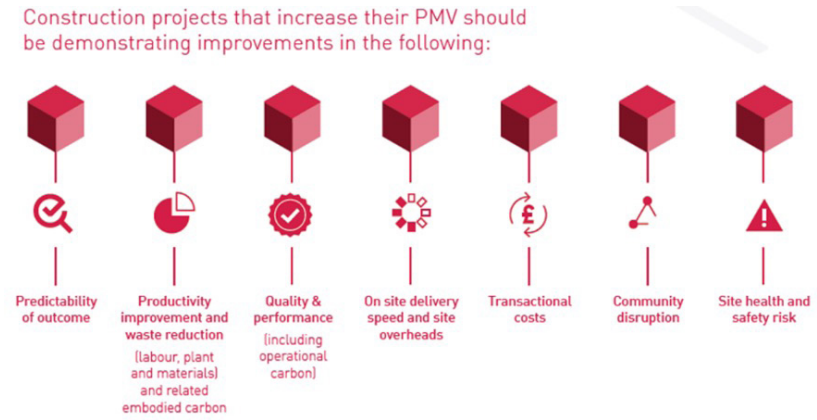
These government drivers are being used to transform housing delivery, providing disruptive influences to move the market towards embracing MMC, with the associated benefits, as indicated below.

***Figure 1.* MMC Benefits and Key Definition Documentation sources**



Ref (1) http://www.cast-consultancy.com/wp-content/uploads/2019/03/MMC-I-Pad-base_GOVUK-FINAL_SECURE.pdf

Ref (2) https://www.cast-consultancy.com/pmv/assets/pdf/PMV_technical%20manual_FINAL.pdf



From section 1. of Ref (2)

Figure 2. ***Definition of PMV (Pre Manufactured Value)***

From section 1. of Ref (2)

Pre-Manufactured Value, known as **PMV**, was first set out in *The Farmer Review*[1] in 2016 as a metric to measure the proportion of manufactured components within an overall construction project cost. The metric, expressed as a percentage, is intended to identify how far projects are implementing innovative construction techniques that result in reduced site labour and preliminaries intensity.

Figure 3. ***MMC Definitions***

Figure 4. ***Category 2 Panelised MMC System Classifications***

4. AIMCH PROTOTYPING: CAT 2 PANELISED MMC SYSTEMS

AIMCH focus is on building a weatherproof, insulated, and secure structural shell in one day, ideally with no scaffolding and a pre-tiled roof. AIMCH partners have built several homes using Cat 2 MMC techniques to prove the case for scaling up using increased levels of panelised MMC prefabrication, in a progressive way This requires the use of a crane and the increased utilisation of the following current and future panelised MMC solutions:

Current Advanced Panelised MMC systems:

a. Insulated closed panel MMC wall systems
b. Pre-fitted windows & doors
c. Ground erect roof systems (built prior)
d. Prefinished floor cassettes
e. Pre-loaded dry lining and stairs components

Future MMC developments:

f. Scaffold-less erect systems
g. Pre-tiled roof & lifting systems
h. Pre fitted weatherproof stairs
i. Prefabricated bathroom/en-suite pods
j. Pre-fitted external claddings

AIMCH partners believe that a progressive approach to embrace increasing levels of PMV offers the most cost-effective, reliable, robust and scalable MMC solution, as part of an industrialised housing approach. Timber-based Cat 2 MMC solutions offer a proven track record of delivering a cost-effective alternative to masonry housing construction.

This progression is shown in the maturity diagram below, in terms of MMC generations. In simple terms, the further along the spectrum you progress, the greater the levels of prefabricated elements used within the structural shell of the building. GEN1 is current open panel timber frame, using loose joists & trusses with open panel walls, manually erected with the aid of material handling using a forklift truck. This represents approx. 70% of timber frame used today.

Increasingly, GEN2 and GEN3 systems are being used, which have progressively more prefabricated elements such as floor cassettes, pre-fitted windows and insulated closed walls. These systems require a crane to offload and position them on site. The PMV value increases as the level of prefabrication increases.

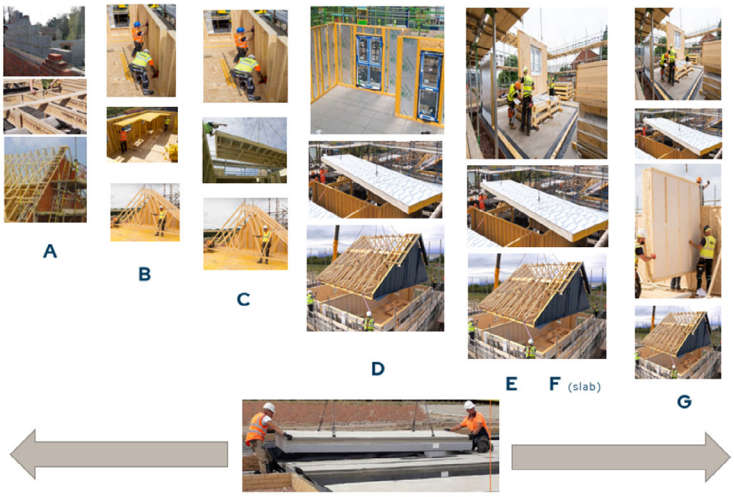
Figure 5. Cat 2 Timber Frame MMC maturity and early stage PMV estimates

55% PMV THRESHOLD (Homes England Grant Funding)

PMV Percentage	45.14%	47.19%	48.39%	53.86%	55.73%	56.98%	56.98%	56.98%	57.38%	61.63%	64.53%
Build Sytem Ref	Base - Masonry	A	B	C	D	E	F	G	H	I	J
Generation Name	0	1	2	3	4	5	6	7	8	9	10
Market Readiness	Current	Current	Current	Current	Current	Current	Emerging	Emerging	Future	Future	Future
Build System Elements	Masonry	Open TF	Open TF	Open TF	Closed TF	Closed TF	Closed TF	Closed TF	Closed TF	Closed TF	Closed TF
	Joists	Joists	Cassettes	Cassettes	Cassettes	Cassettes	Cassettes	Cassettes	Cassettes	Cassettes	Cassettes
	Trusses	Trusses	Trusses	Trusses	Trusses	Trusses	Trusses	Trusses	Trusses	Trusses	Trusses
	FLT	FLT	Crane	Crane	Crane	Crane	Crane	Crane	Crane	Crane	Crane
				PIR Preinsulated	GW Preinsulated	GW Preinsulated	GW Preinsulated	GW Preinsulated	GW Preinsulated	GW Preinsulated	GW Preinsulated
				FFW	FFW	FFW	FFW	FFW	FFW	FFW	FFW
				GER	GER	GER	GER	GER	GER	GER	GER
	Optional : Prefricated Floor Slab (applicable to all)					Prefab Slab	Prefab Slab	Prefab Slab	Prefab Slab	Prefab Slab	Prefab Slab
							Closed PW	Closed PW	Closed PW	Closed PW	Closed PW
								Site Façade System	Site Façade System	Site Façade System	Site Façade System
									Scaffoldless Erect	Scaffoldless Erect	Scaffoldless Erect
									AR Roofer	AR Roofer	AR Roofer
									Pre Tiled Roof	Pre Tiled Roof	Pre Tiled Roof
										Wet Room Pods	Wet Room Pods
											Kitchen Pods
											Services Pod

40% PMV MINIMUM THRESHOLD **70% PMV MAXIMUM THRESHOLD**

Figure 6. Pictorial Cat 2 Timber Frame MMC maturity and early stage PMV estimates



A – Masonry (Baseline) 45.14%
Masonry, loose joists and roof at height

B – GEN1 – 47.19%
Open panel TF, loose joists & roof at height

C – GEN2 – 48.39%
Open panel TF, floor cassettes, site overlay flooring & roof at height

D – GEN3 – 53.86%
Open panel TF, pre-insulated walls (PIR), factory fitted window, prefinished floor cassettes, ground erect roof

E – GEN4 – 55.73%
Closed panel TF, pre-insulated walls (BLOWN FIBRE), inner service batten, factory fitted window, prefinished floor cassettes & ground erect roof.

F – GEN5 – 56.98%
GEN4 + prefabricated floor slab

G – GEN6 (Emerging) **– 56.98%+** (should be higher)
GEN5 + Closed party walls

NOTE: Prefabricated floor slab applicable to all.

5. H&S RISK PROFILING CONCEPT

All AIMCH partners use a range of construction systems including masonry and open and closed panel timber frame MMC. All systems are safe in that they comply with applicable HS&E requirements: risks are identified, control actions are implemented to minimise the risk of safety events arising and reportable events are documented. The concept of one system being safer than another when all systems are safe and compliant is somewhat counter intuitive and not currently supported by evidence.

This has led to the consideration of risk profiles and their distribution across the supply chain. It is recognised that differing approaches will lead to differing safety management systems and changed exposure to types of risk. A developer's safety outlook is typically impacted by their attitude towards safety hazards, risk mitigation and the management of safety.

The focus of this study was on assessing the difference in risk exposure between two timber frame systems: one built on site with the aid of a forklift and manual assembly techniques (GEN1) and a second, more advanced MMC system, built with the assistance of a crane and higher levels of prefabrication (GEN3).

As introduced in the Overview section, "Deep Dives" were undertaken on the following two construction solutions to establish comparisons of risk exposure. In each case, GEN3 is designed to increase the level of offsite prefabrication and simplify construction assembly on site. The deep dives carried out were:

1. GEN1 forklift & loose joists v GEN3 crane & MMC floor cassettes
2. GEN1 forklift & site fitted windows v GEN3 crane & factory fitted windows

These two areas were selected to highlight the different H&S considerations and risk profiles associated with each construction solution. For each area, hazards were identified, and mitigation processes suggested. These focused on the following key safety areas:

1. Falls from Height
2. Manual Handling
3. Traffic Management
4. Lifting Operations
5. Material Handling
6. Slips and Trips

Note that, for the purpose of the risk assessment process described in Appendix 4-8, the risks from the HSE Construction Industry Risk Profile Areas (IRP) in Appendix 3 have been grouped into the following categories (see Appendix 7) for display on the radar plots:

- Collapse; Collisions; Falls; Handling & Lifting; Machines; Noise & Vibration; Other; Respiratory; Slips & Trips

5.1. Risk assessment scoring scheme

Appendix 4 describes the approach to setting the Risk Exposure (item 1) and Impact levels (item 2), which are then given a numerical score from a look-up table (item 3):

1. Risk Exposure was defined using a 5-level scale from Very Low (<1hr exposure per week) to Very High (>30 hrs per week). This estimates how many hrs per week an operative is actually exposed to the risk of an event, whether it is mitigated or not.
2. Impact is defined as the likely worst case that could occur if the risk materialised, e.g. a slip or trip could result in incapacitation for several days, whereas the overturning of a forklift or crane could result in death. The Impact levels use the RIDDOR-reportable levels from Low to Very High impact and Non-reportable for Very Low impact.
3. After selecting the appropriate "Exposure" level and the potential worst case "Impact" level, a resulting "Overall risk score" or "Risk Exposure" figure can be obtained from the look-up table.

5.2. Risk assessment of Case Studies 1 and 2

The resulting scores of the risk assessments carried out for each of the two case studies introduced in section 2 are presented in Appendix 5 and Appendix 6. It should be noted that these risk assessments are the judgements of the authors, and are not based on numerate data, which was not available for this study. The judgements were based on perception of the amount of time spent on the activities and the possible worst-case impact of an event. However, there is supporting evidence for the assessments presented in this report from sources such as (3), which reports the following

i. Injury rate/100,000 workers in Construction that is 42% higher than in manufacturing
ii. 50% of deaths in construction are attributed to falls from height, compared with 16% in manufacturing

Further supporting evidence may be provided in future analysis of the time spent on-site for various activities, comparing traditional and MMC-built homes.

5.3. Risk assessment category groupings

As mentioned above, the risk assessments were conducted against a subset of the risks listed in Appendix 3, which were deemed to be in-scope for this report. Appendix 7 lists these and groups them appropriately to make comparisons easier.

5.4. Overall risk exposure comparisons

Having gone through the steps described above, a total risk exposure for GEN1 and GEN3 construction solutions for each case study can be concluded. The risk exposure for each of the groupings of risk can also be seen. This is shown in the radar plots presented within the following sections for each case study. These radar plots shows differing "Risk Exposure" shape of the construction solutions on site.

The conclusion of this assessment is that the GEN3 construction solution could demonstrate a 19-20% reduction in on-site risk exposure, compared with GEN1. This does not imply that GEN3 is safer than GEN1, but it does indicate the differing risk exposure profiles on-site and should therefore drive the appropriate safety management requirements

As has been stated earlier, this must not be taken in isolation, since there is therefore a transfer of risk to the MMC factory for all those operations that would normally be carried out on-site for a GEN1 construction solution. The management of risk in the MMC factory is therefore critical to the successful implementation of MMC solutions, since if risk is not adequately managed in the MMC factory, then overall risk exposure could increase across the value chain.

Sophisticated approaches to risk assessment are commonplace in other sectors. For example, in aerospace it is recognised that a worst-case catastrophic event can occur, but is extremely unlikely, with significant built-in design features, testing and operational controls designed to minimise the likelihood of significant events to incredibly low levels.

In some situations, many lower-level risks can build up over time and result in long term health issues, which may not be seen as catastrophic in the near-term, e.g. musculoskeletal disorders and respiratory diseases. Therefore, the definition of being “safer” can be seen as subjective, and it often correlates to the safety attitude of an organisation, even if they are fully compliant with recognised H&S requirements.

A key observation from this assessment is that, as PMV is increased, then there will be an increasing level of risk transfer from building site to MMC factory, which may be very attractive to the house builder on site. However, to reiterate, it must be recognised that it is incumbent upon all actors in the supply and value chain to ensure that safety systems are in place on the shop floor as well as on site, to ensure a net safety gain is achieved, to the benefit of all stakeholders and to wider society.

6. CASE STUDY 1: GEN1 LOOSE FLOOR JOISTS V GEN3 FLOOR CASSETTES

Table 2 compares the onsite construction of GEN1 upper floor structure, comprising loose joists, ironmongery, blocking and flooring which are site fitted, from safety decking to GEN3 upper floor structure, comprising prefinished floor cassettes with joists and flooring all prefabricated and no safety decking.

For this comparison, there is no crane involvement in the GEN1 process, but a forklift has been assumed, to assist with loading of materials into a plot, via first floor scaffolding loading bay.

Table 2. ***Case study 1: GEN1 loose joists vs GEN3 floor cassettes***

Industry Risk Profile (IRP) Category		GEN 1 Forklift Erect - "Traditional Loose Joists"		GEN 3 Crane Erect - "MMC Floor Cassettes"	
		Hazard Burden	Associated processes	Hazard Burden	Associated processes
8	Fall from open edge	Incorrect installation and management of safety decking risks associated with gaps and collapse.	**Delivery and Storage** • Materials arrive on site via lorry days before installation. • Offloaded using a forklift and stored in designated storage area. **Movement** • Safety deck installed as per manufactures guidelines for use as a working platform only. • Joist pack loaded using forklift. For upper floors it is landed on load bearing panel wall heads or vis scaffolding loading bay. • Joist pack is opened, and joists spread manually in accordance with the drawing. Minimum 2 people, exposed for up to 3 days lifting, bending, carrying materials, weather exposure. **Installation** • Fitting involves installation of an edge binder to the full perimeter of floor zone. Joists are installed tight to the edge binder and nailed. • Flooring sheets loaded with forklift and then manually lifted and laid on floor • Access is off working platform requiring operatives to walk over and across joist bays, with potential for trip and injury • Floor sheets manually moved from the forklift onto the joists and temporary longitudinal bracing installed and nailed to the top of the flooring, as per floor manufacturer instillation guide. • Common equipment used includes circular saw, hand saw, nail gun and other hand power tools	Climbing onto top of lorry to sling. Accessing deck from top and unprotected leading edge. Use of hop-ups underneath the installed cassettes	**Delivery and Storage** • Factory constructed prefinished (joists, flooring, protection, lifting slings all prefabricated) floor cassettes arrive on the day of erection on an articulated lorry and un-strapped. **Movement** • Crane - moves floor cassettes from lorry to designated laydown area. • Lifted by crane - using pre-fitted slings which are then removed from the underside once cassette has landed. **Installation** • Draw strings - pre-attached to floor cassette stack to prevent climbing on lorry to remove banding straps. • Cassette stacks are slung from ground level and lifted by crane to laydown area • Tag lines attached to guide cassettes during lifting operations. Cassettes landed in sequence starting at agreed point within the house. • Cranking tools used to ensure cassettes flush, level, and maintain structural integrity. • Screws used to draw the cassettes tight and flush, to agreed detailing • Task of installing floor cassettes normally takes 2 joiners 1-2 hours to complete. • Installation is always from underside off podium steps or scaffolding with handrail, until all floor cassettes are in place and safe to access deck • Stairwell opening - have pre-fitted temporary infill panels, designed to fill hole and easy to remove from underside, whilst edge protection is fitted . • Lifting Operations - Lift plan is prepared and agreed prior to lift day. • Competent persons - Crane operator is qualified and Appointed person in place and lift supervisor present during set up, lifting and derigging. • Crane set up locations are pre agreed and cordoned off. Access is limited around lift areas and crane location, as part of lift plan and prior preparation
9	Fall from Scaffold	Stairwell openings are formed on site and require temporary protection/infill to reduce potential to fall and exposed leading edge safety hazard		Internal edges from scaffold prior to placing cassette.	
13	Machinery Guarding	Required for handheld circular saw for cutting loose joists		Reduced requirement for handheld power tools for cutting timbers to size	
14	Materials Handling inc. Manual handling	Handling and carrying flooring & joist components			
15	Mechanical Lifting Operations	FLT overturn while lifting heavy loads to upper floor levels, scaffolding bays.		Crane while lifting floor cassette. Boom sling collision with objects if not guarded	
17	Noise	Noise from power tools used for fixing and cutting materials. Noise from vehicles and bleepers.		No ear protection required for GEN3 cassettes. FLT not required for offloading and fewer vehicle deliveries, so less bleepers and vehicle noise around site	
22	Slip or trip on same level	While handling heavy loads, due to ground conditions, housekeeping, or weather Operatives must walk on temporary safety platform, crossing over joists and between joist bays, where risk of trip is high.			
23	Struck by a falling object			Working inadvertently under cassette when being lifted and laid into position, sling collapse or cassette failure, traps, or lands on person below	
25	Sruck by moving vehicle	FLT during movement of materials around site and within plot.			
26	Unintended Collapse	Installation of safety decking system and management in use, risks associated with gaps and collapse. Joists packs and structure, flooring stacks and safety decking can be prone to collapse if not stacked correctly, when banding is cut, or temporary bracing is not fit for purpose		Destabilised floor cassette if not installed correctly - slips off end of bearing if not landed correctly or walls not braced correctly	
27	Using hand/ power tools	Nail gun and circular saw		Nail gun and circular saw	
28	Vibration	From power tools			
30	Wood dust	From power tools for cutting. Masks required.		No cutting required. No masks required.	
31	Other	Weather exposure for site staff, up to 3 days, increasing risk from wet/ cold weather working.		Reduced exposure to weather.	

6.1. Risk Considerations:

Table 2 above shows the potential for a reduction of on-site hazard burden, associated with the two processes. The detail below considers the likely actual difference, in the nature and levels of the associated risks, exposure and headings grouped under safety themes.

*Figure 7. **GEN1 Loose joists, safety decking and forklift installation***

*Figure 8. **GEN3 floor cassettes, no safety decking and crane installation***

6.2. H&S Risk Profile and Hazard Reduction Considerations

The Information above shows a significant reduction in the on-site hazard burden associated between the two processes. The detail below considers the likely actual difference in the nature and level of associated risk, grouped under the themed headings.

The GEN 1 build method can take up to 3 days to install, utilising safety decking, manual offloading and placement of joists and floorboards. This construction method has many inherent risks built into the process. Working at height, manual handling, trips and slips and material movement operations are significantly more than the GEN3 prefabricated floor.

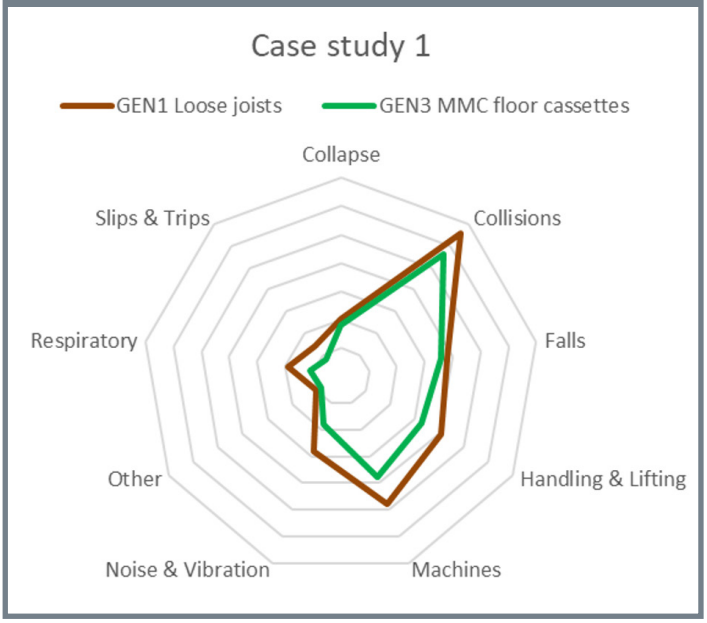
The GEN3 floor cassette method can take 2 hours to install. Cassettes are crane landed into position with no working below slung loads or access to deck permitted. All access is off podium steps from the underside after cassettes are landed into position. Access to the finished floor deck is permitted after all floor cassettes are landed with a full 4 sided scaffold and edge protection being in place. The exposure to wet/cold weather working is significantly reduced and manual handling/material movement eliminating. The use of floor cassettes designs out the requirement for temporary working platform (Safety Decking). This is a significant cost and time saving. Safety decking requires competent persons, supervision and sign-off. Some developers are moving away from using this measure due to increase safety decking collapses.

The findings clearly show eliminating site fitting of loose floor joists, safety platforms and chipboard flooring offers a significant risk/hazard reduction benefit, when using the GEN 3 Floor cassette construction method.

It is recognised that the use of floors cassettes requires a crane and more complex LOLER compliance requirements. In this case the "Risk Exposure" of the two approaches changes. This is shown in the following H&S risk profile radar plot.

This data indicates a reduction in risk exposure between GEN1 and GEN3 across all 9 categories assessed, particularly for Handling & Lifting, Machines and Noise & Vibration.

Figure 9. On-site H&S risk exposure comparison: GEN1 Loose Joists vs GEN3 MMC Floor Cassettes



6.4. Falls

The use of prefabricated floor cassettes substantially reduces the time and number of workers are exposed to falls risks. The factors associated with any fall also differ. In GEN1 the risk is mostly related to installation of the safety decking system, floor structure and floorboarding, including the management in use risks associated with gaps and collapse, arising from the safety decking system.

In Gen 3 this is related to falls associated with any exposed edges from scaffold prior to placing cassette and the use of hop-ups, as well as podium steps used from underneath the installed cassette, to remove the pre-fitted sling. The stairwell is fully protected with a temporary infill panel pre-fitted to eliminate risks from falling. Access from ground level is required when attaching the lifting hook to unload cassettes and attach slings to lift cassettes into place.

All factory installation work is on the same level, standing on the ground, eliminating risks of falls in the factory environment. Any reduction in the use of scaffolding hop ups etc compared to GEN1 floor installation will further improve safety. Gen 3 eradicates the need for a safety deck and less assembly and disassembly, of the scaffold thus reducing the risk of falls associated with exposure.

Figure 10. ***GEN1 Loose Joists Construction Method***

6.5. Moving and Handling

MSD risks associated with moving and handling are outlined in HSE's Manual Handling Assessment (MAC) Tool (4). GEN1 requires the moving and handling of safety decking, timber joists/beams, noggins, and flooring. The risks are largely dependent on weight and frequency. Typical material weights are:

70kg for joists/beams size

25kg for flooring

10kg for safety decking

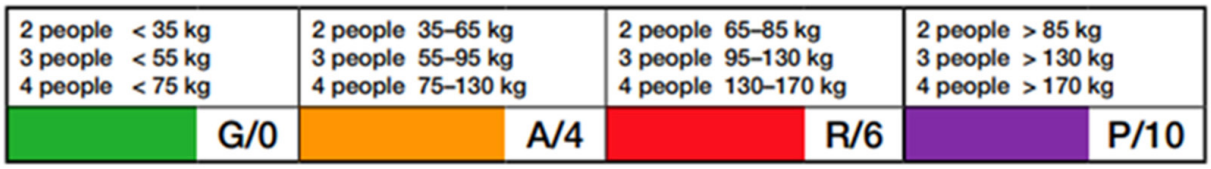
Joist and beams present the biggest weight issue, in that some elements can be very heavy i.e., timber beams around openings. In themselves these weights may not seem significant; however, they are repetitive, awkward to handle, and associated with lots of bending, stooping, stress, reach, and kneeling which can cause many MSD issues. As MSDs risks are cumulative a significant reduction in the overall exposure during the working life of an operative is an important consideration.

Figure 11. ***HSE Manual Handing Weights and Risk Classifications***

6.6. Slips and Trips

GEN3 has two significant benefits over GEN1. Firstly, there are no exposed joists present, that provide many individual trip points, until these are covered by the flooring. Secondly, a significant cause of slips and trips is poor housekeeping. GEN1 requires the cutting of material which generates stock near the workplace and waste products. If not adequately controlled these will give rise to an element of risk.

Figure 11. ***HSE Manual Handing Weights and Risk Classifications***



6.7. Using Hand or Power Tools

GEN3 will reduce these risks on site, as there is significantly less fixings to be installed due to the high extent of prefabrication. GEN3 cassettes require minimal fixing and use ratchet and pneumatic tool to draw cassettes joints together and secure in place. There is no requirement for cutting and fitting of cassettes, eliminating use of blades and dust/noise related issues. It is recognised that fixings are displaced to the factory environment. It is therefore incumbent on the MMC supplier to ensure appropriate safety controls are in place within the factory environment. This will ensure there is a net gain in the reduction of safety events, arising from using of tools.

6.8. Struck by Moving Vehicle

The different risk profile associated with workplace transport is considered in more detail in lifting operations and vehicle movements. In general, GEN3 will remove transport risks linked to forklift truck movements while moving safety decking, timber joists/beams and flooring products, around site and within plots, including the increased risk of lifting to upper floor levels.

6.9. High Impact Events:

6.9.1. Overturn and Lifting Operations:

GEN3 removes forklift truck overturn risks that are associated with lifting joists and flooring sheets to a first-floor landing platform. This would be in proportion to the number of movements required to offload, handle and position materials around site that are eliminated. These are transferred to the overturn risks associated with use of GEN3 crane, and considered in more detail in the sections on vehicle movements and lifting operations (see 7.7 and 7.11).

6.9.2. Unintended Floor Cassette Collapse:

This is an additional risk compared to GEN1 and is associated with the installation of the large pre-manufactured floor cassettes. These weigh up to 400kg each and can measure 12m by 3m in size. If they are not lifted, landed, located and fixed correctly, then cassettes could collapse, break their slings and slip off the end bearing when being placed. If this was to arise, then anyone in the immediate vicinity could be crushed.

Figure 12. ***GEN3 Floor Cassette installation***

6.10. Displacing Risks to MMC Factory Environment

The AIMCH MMC trials and analysis undertaken, on GEN3 Floor Cassettes, clearly shows a significant reduction in site-based risk and hazard exposure. Clearly this is a major benefit to constructors. However, it is recognised that merely displacing the risk to a factory environment, from an overall H&S perspective, may not provide a net reduction in risk/hazard exposure, to the benefit of overall H&S improvement.

That said there is clear potential to reduce risk and hazard from a controlled factory environment that would not be the case on a building site. In addition, the introduction a wide range of risk mitigation measures, is more likely to be feasible and viable in a factory environment, than would be the case on a building site. Building sites are exposed to weather, lack work continuity, dependent of transient sub-contract labour and have less supervision, than factory environments.

6.11. Management Arrangements

A key consideration is the fundamental shift in focus, of pre-construction management activities, to suit the GEN3 floor cassette method. This requires a design for manufacture and assembly approach (DFMA).

Its fundamental the MMC supplier/installer is involved early in this process. This is critical to ensure efficient, successful, and safe delivery of the project.

- Pre-Construction Phase: The GEN3 floor cassette method requires additional health and safety management arrangements regarding the use of a crane and displacement of risk to the MMC factory environment. More planning, coordination and design considerations are needed early in the process to ensure materials arrive at the factory, are properly installed and floor cassettes constructed, that are fully considered as part of the site CDM safety plan
- Construction Phase: The upfront GEN3 floor cassette benefit will be proportionately offset, by the reduced site-based planning, co-ordination, management, installation, and monitoring, needed for site fitting loose floor systems. It is recognised that additional lift management requirements are needed, and appropriate controls will be needed. However, the work, effort and time involved in managing this is significantly less than the safety management of GEN1 loose floor joist constriction.

6.12. Future Factory Automation & Robotics

As the market matures for MMC systems and factory assembled floor cassettes, this becomes an increasingly attractive commercial, safety and construction benefit the MMC supply chain needs to develop solutions which overcomes the safety risk displacement, welcomed by constructors, so that there is a net gain in overall safety improvement across the entire construction and manufacturing sector.

Increasingly, MMC suppliers are looking towards investing in technology to reduce labour dependency within the shop floor and improve productivity. This has been evident within the automotive sector. This learning can be transferred to the MMC sector to bring about industrialised change within the sector that overtime delivers a net safety gain to the community. Technologies used and being explored by some MMC suppliers include assisted vacuum lifting/placement and robotic placement/fixing of floor joist and decking elements.

Figure 13. ***Example of automated board placement, fixing and gluing***

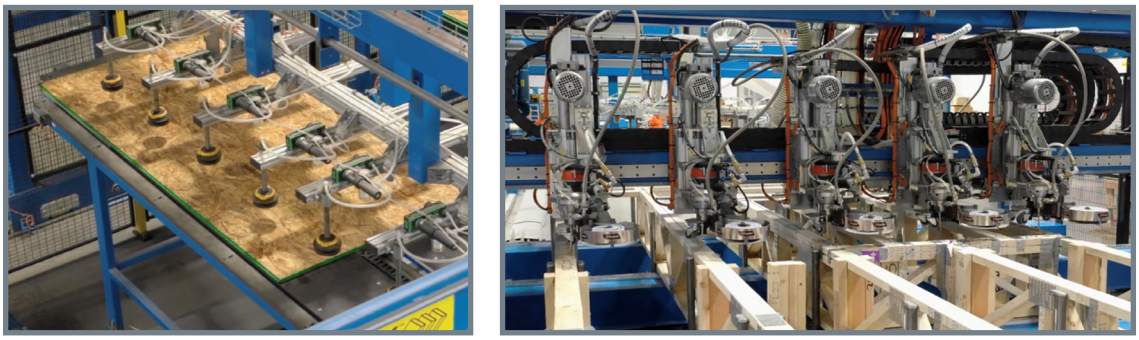


Figure 14. ***Example of automated floor cassette production***

6.13. Summary of Case Study 1

There is a fundamental safety improvement between the two methods. GEN 1 loose joists rely on more manual labour and material movement on-site and the installation of a safety decking system. GEN3 floor cassettes significantly speeds up the process and removes many of the risks associated with it. However, the installation of pre-manufactured cassettes brings with it new risks associated with the movement of large heavy loads.

In general, it is a difference between a shorter process with several high hazard processes (lifting and installing via crane) compared to a process with more hazards, some of which are also significant, to which people are being exposed to over a more extended period.

7. CASE STUDY 2: GEN1 SITE-FITTED VS GEN3 FACTORY-FITTED WINDOWS

Table 3 below compares the on-site fitting of windows to pre-formed structural openings within the timber frame panels (GEN 1), to the factory fitting of windows, which arrive on site pre-fitted as part of the timber frame kit (GEN 3).

This only applies to windows up to 2.7m wide, by 1.9m high & 120kg max weight due to factory fitting limitations.

It is not possible to factory fit every window component, due to building design, complexity, sequence, size, or weight restrictions. Examples include:

1. Bay, corner, and feature oriel windows
2. Stairwell windows split across floor levels
3. Very large windows – out with the maximum size range
4. Very heavy windows - greater than 120kg
5. Bi-fold, French, or patio doors
6. Front and back external pass doors
7. Dormer & roof light windows.

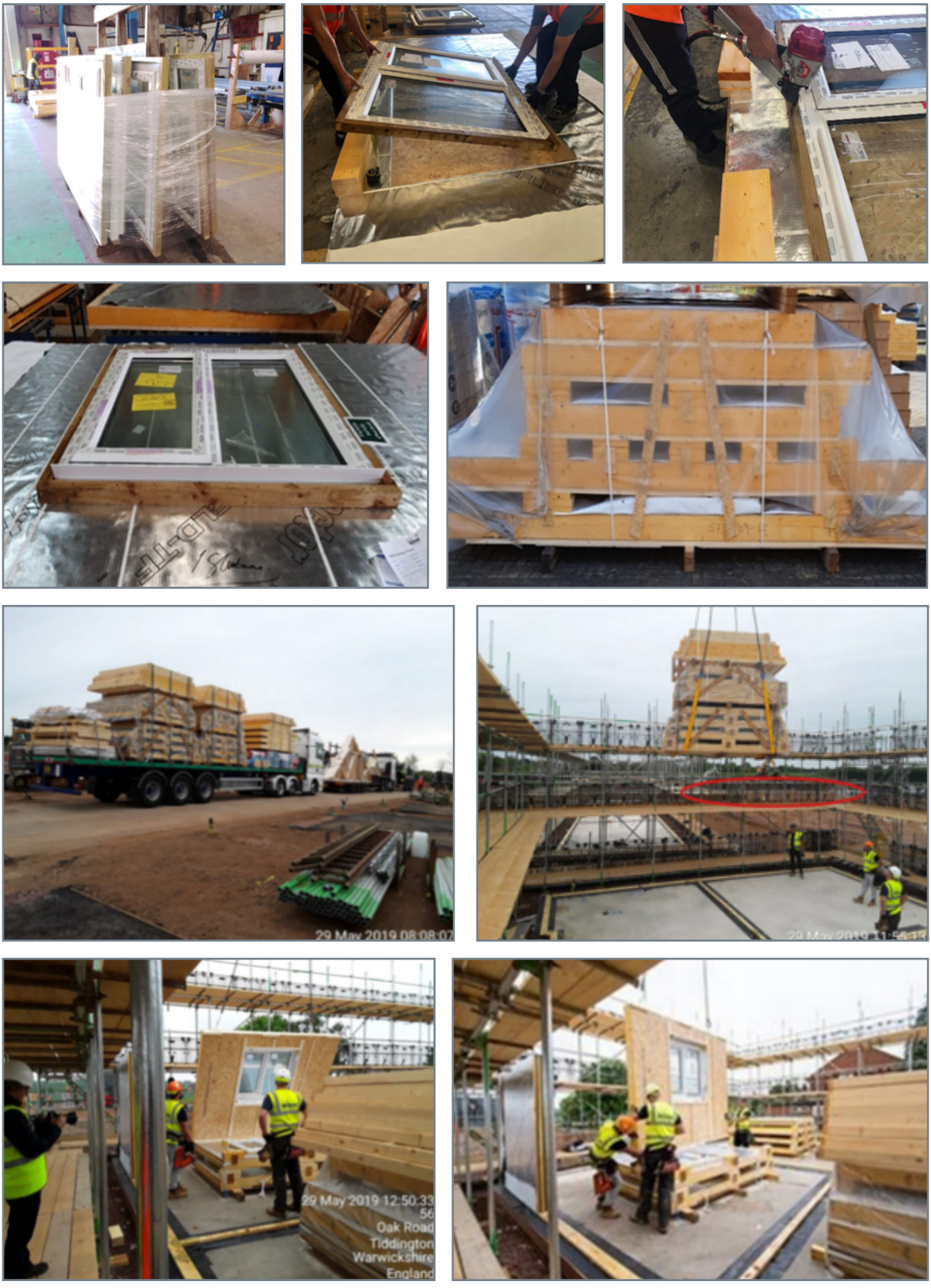
Table 3. ***Case Study 2: GEN1 Site fitted vs GEN3 Factory Fitted Windows***

Industry Risk Profile (IRP) Category		GEN 1 Forklift Erect - "Site Fitted Windows"		GEN 3 Crane Erect - "Factory Fitted Windows"	
		Hazard Burden	Associated processes	Hazard Burden	Associated processes
8	Fall from open edge	While using hop-ups or loading bays to provide access to or installing above ground floor.	**Delivery and Storage** • Arrive on site via lorry 1-3 days before the kit and 2 days before installation. • Windows and doors strapped to stillage's, wrapped, protected, and placed on pallets • Offloaded using a forklift and stored outside, in the designated storage area. **Movement & Handling** • Forklift moves windows adjacent to plot, and stored on external ground ready for unpackaging • Unpackaging - window stacks are unstrapped and unwrapped and manually re-organised in GF/FF lots • FF lots are lifted by FLT to scaffolding loading bay and manually offloaded at height • Team of 2 joiners lift and carry windows through scaffolding to GF and around FF scaffolding to locations adjacent opening. • Access to mid/semi-detached plots is more difficult requiring longer walk time to access front and rear elevations, or access limited by taking windows through GF/FF of building • Windows are temporally placed on side/angle ready for fitting at GF/FF **Installation** • Fitting involves 2 joiners lifting units, locating aperture, sliding into position, temporarily resting/holding weight, and balancing windows on pre-fitted timber fire stops. • Windows are held in place by one operative and second operative nails windows temporarily into place • Windows are checked for line and level and permanently fixed, access is needed form below and above the window to reach all fixing points, requiring operatives to move between scaffolding platforms and reach down/up.		**Delivery and Storage** • Windows are factory fitted and arrive on site as part of the timber frame kit. • Windows are safety checked in factory to confirm fixings are as required • Fixings are designed to accommodate short term lifting loads and stresses **Movement** • All panels with windows pre-fitted are too heavy to manually lift and are pre-slung • Slung, lifted, and installed as part of the same process used for the wall panels Lifting Operations • All lift operations are managed under LOLER regulations with pre-approved RAMS agreed within site safety plan, before work starts • Lifting operations are managed by appointed person and lift supervisor present • Wind speed/gusting is monitored, and no lift occurs if requirements are breached Installation and Handling • Factory fitted windows require no site fixing or handling, due to pre-fitting in factory and by placing wall panel are effectively installed
9	Fall from scaffold				
13	Machinery guarding				
14	Materials handling inc. Manual handling	Particularly to the back and upper body from handling glazed window components. Over stretching to reach fixing points due to limited access and reach.			
15	Mechanical Lifting Operations	FLT while lifting windows from delivery vehicle, transporting windows around site, or loading onto scaffolding loading bay.		Crane while lifting wall panel containing window Struck by crane or boom or walking below suspended load and risk of being crushed. Wind gust suddenly inadvertently swings towards or strikes operative or scaffolding.	
17	Noise				
22	Slip or trip on same level	While handling windows/pallets due to ground conditions, scaffolding or housekeeping.			
23	Struck by a falling object	Struck by a falling incorrectly stacked / placed glazing or during installation either out of aperture or between floor levels		wall panel containing window incorrectly supported, slung, or moves inadvertently during installation Window falls out of opening whilst wall panels are being lifted or placed into position Struck by wall panel while lifting wall panel containing window	
25	Struck by moving vehicle	FLT or delivery vehicle during delivery, offloading and movement/handling around site Risk of accident due to increased deliveries and handling on site			
26	Unintended collapse				
27	Using hand/ power tools	safety issues associated with nail gun used to fix windows			
28	Vibration				
30	Wood dust				
31	Other				

7.1. Risk considerations

Figure 15. ***GEN1 site fitted windows and forklift handing***

*Figure 16. **GEN3 factory fitted windows using crane***



7.2. H&S Risk Profile and Hazard Reduction Considerations

The Information above shows a significant reduction in the on-site hazard burden associated between the two processes. The detail below considers the likely actual difference in the nature and level of associated risk, grouped under the themed headings.

The GEN 1 build method can take the forklift up to fifteen minutes to convey a pallet of windows from the designated site storage area to the designated plot for use. As soon as the windows are placed near the plot, a team of two joiners will start unstrapping and manually placing them at the specified locations around the GF/FF scaffolding, as per the layout drawings.

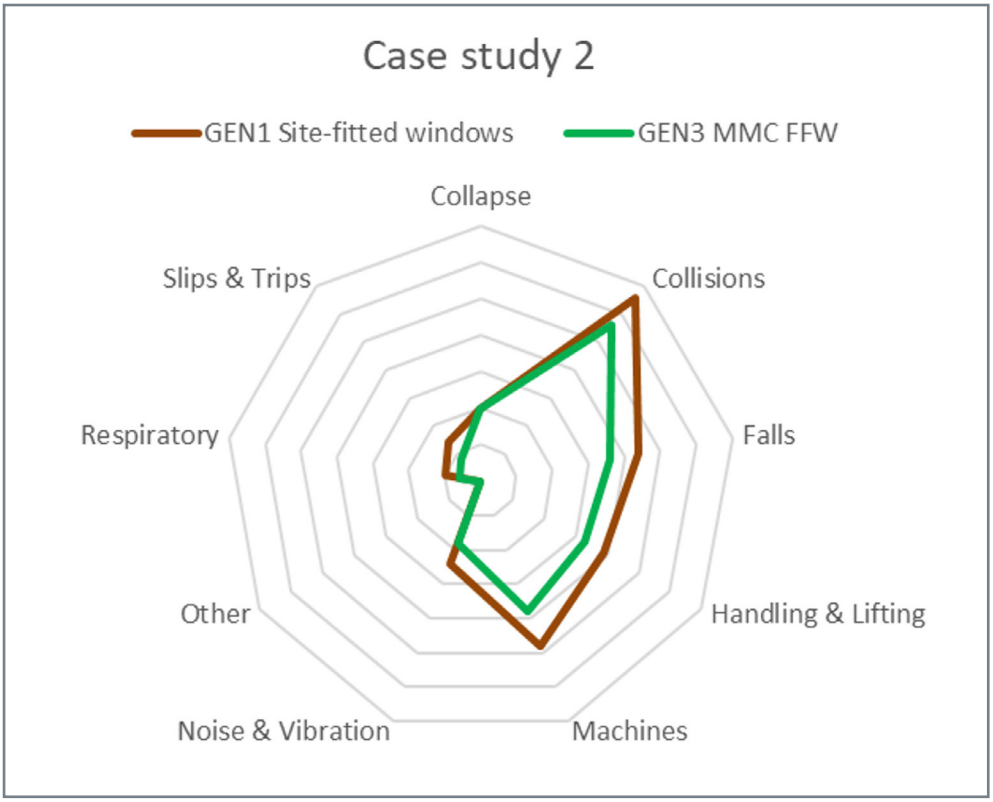
The task of placing eight windows at the specified locations takes, two joiners on average just over 4 hours per house to locate and fit the windows. These timings are heavily dependent on the house type, number of windows and their dimensions/complexity.

When the windows are pre-fitting all these on-site activities, operative time and the associated risks/ hazards can be fully eliminated.

In the future, the factory fitting of external doors will eliminate the need for site fitting these elements. In addition, through Design for Manufacture and Assembly (DFMA), it is feasible that more complex window designs (as noted above) could be designed out so that all windows can be factory fitted.

However, eliminating site fitting of windows (up to 2.9 x 1.9m or 120kg) offers a significant risk and hazard reduction using the GEN 3 panelised MMC build system. This is further detailed below.

Figure 17. ***On-site H&S risk exposure comparison: GEN1 Site Fitted Windows vs GEN3 Factory Fitted Windows***

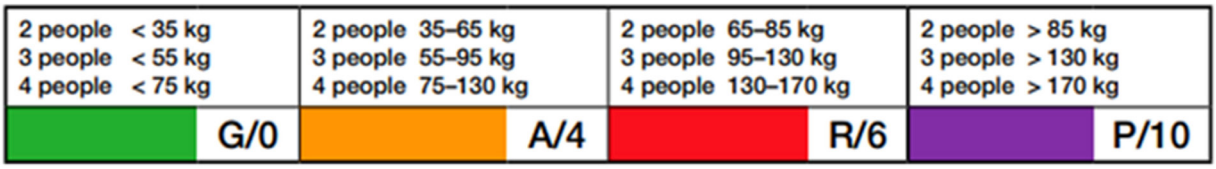


This data indicates a reduction in risk exposure between GEN1 and GEN3 across most of the 9 categories assessed, particularly for Collisions, Falls, Handling & Lifting and Machines.

7.3. Musculoskeletal Disorders

MSD risks associated with moving and handling are outlined in HSE's MAC tool as outlined in the table below. Windows can present a significant risk depending upon their weight and how frequently people are supporting that load.

Figure 18. ***HSE Manual Handing Weights and Risk Classifications***



- The maximum weight for a window to be factory fitted is 120kg. This safeguards windows classified as Red and Purple, high risk where multi operatives are needed on site.
- The average time for moving and installing site fitted windows was about 22 minutes per window. Using these figures, moving, and handling a window would be in the amber range for a single joiner when the weight of a unit starts to get to around 18 kg and then red at around 36kg.
- Where the joiners lift and carry together, these figures increase to around 35kg and 65kg respectively.
- Other MSD risk consideration will be linked to ergonomic constraints linked to site conditions. There are likely to be primarily associated with access difficulties created by scaffolding and the bending / twisting required during the installation process.

GEN3 factory fitted window build system removes/reduced all on-site GEN1 risks, in proportion to the number of factory-fitted windows installed.

The MAC tool identifies there being an unacceptable level of risk (purple category) where two people are carrying more than 85kg or three people 130kg.

It is appreciated that the most significant risk/hazard reductions, associated with external doors, are still to be realised. In addition, many of the GEN3 moving and handling risks, are displaced to the factory fitting process. Consequently, the case for a net health and safety benefit, needs to consider the factory safety processes.

7.4. Displacing Risk & Hazards – Site to Factory Environment

The AIMCH MMC trials and analysis undertaken, on factory fitting windows, clearly shows a significant reduction in site-based risk and hazard exposure. Clearly this is a major benefit to constructors. However, it is recognised that merely displacing the risk to a factory environment, from an overall H&S perspective, may not provide a net reduction in risk/hazard exposure, to the benefit of overall H&S improvement.

That said there is clear potential to reduce risk and hazard from a controlled factory environment that would not be the case on a building site. In addition, the introduction a wide range of risk mitigation measures, is more likely to be feasible and viable in a factory environment, than would be the case on a building site. Building sites are exposed to weather, lack work continuity, dependent of transient sub-contract labour and have less supervision, than factory environments.

7.5. Pneumatic Powered Hand Tools

GEN 3 factory fitted windows removes the need to use pneumatic nail guns to fix windows on-site, eliminating this GEN1 risk. However, essentially the same equipment is used in the factory installation. There is a marginal net health and safety benefit, save for its use, in a potentially more controlled factory environment, governed with sound H&S practises.

Fully automating the factory fixing of windows, for example by a robot, has the potential to eliminate this hazard all together. MMC manufacturers are already considering future innovation, that seeks to increase use of automated and robotic fixings systems, so it is feasible that this risk could be eliminated by those forward thinking MMC producers, in the long term.

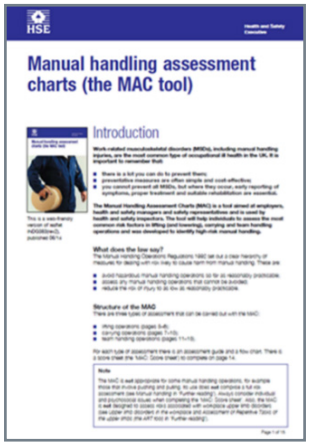
*Figure 19. **Site v Factory Nailing Process, Reach and Access***

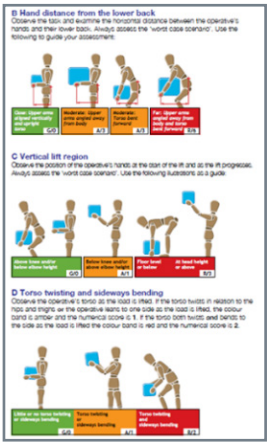
7.6. Manual Handling

GEN3 factory fitted windows removes associated manual handling this on-site GEN1 risk. Factory fitted windows eliminates the need to carry, place and store windows on site. GEN1 processes has an inherent risk that windows could fall over or drop from height for example through scaffold hop-ups to levels below. It is also recognised that lifting windows manually as a two-man operation and walking these around scaffolding or across uneven ground does present a risk of operative falling from height or falling over, where injury could be severe.

All factory offloading and distribution of windows is done on a flat level hardstanding, using trained and component forklift drivers. The storage of windows is simplified by using a-frame or pallet handling systems and internal suitable storage racks or laydown locations. All material flows are well managed from receipt, handling, and distribution to production, by multiple in house qualified and skilled warehouse operatives, supervisors, and managers. The physical fitting of windows in the factory is on one level horizontal work bench with any lifting of window components mechanically assisted, via scissor lifts, vacuum sucker lift or gravity fed roller tables, to minimise manual lifting.

*Figure 20. **HSE MAC Manual Handling Assessment Tool & GEN1 site fitted window process***





7.7. Site Traffic Management

GEN3 factory fitted windows reduces the amount of site traffic movement on the building site. Generally, this is welcome safety benefit in the eyes of constructors. By combining the timber frame and window delivery into one delivery, one set of vehicle deliveries and forklift use can be eliminated. On a typical 100 home development this eliminates 70 delivery trucks and reduces forklift time by circa 300 hours.

The reduction on vehicles on the site, reduces the hazard of being struck by a vehicle or having to interact with moving vehicles daily. Reducing workplace transport is considered good practise objective. Reducing forklift use is not only safer, but more efficient freeing up forklift to service other trades and reducing active time moving on the site. In addition, ancillary benefits include the reduction in window a-frame stillage or pallets, that require collection and storing on site.

Clearly displacing fitting of windows to a factory environment, may not reduce traffic movement, at a holistic level. Deliveries are still needed direct to the factory. However, it is recognised that the management of receiving, offloading, storing, and distributing goods within a factory environment can be more easily managed. That said the new safety gain maybe marginal as accidents and hazards can still arise within the factory environment, where workplace traffic is poorly managed or unsafe systems tolerated.

7.8. Falls from Height

GEN3 factory fitted windows alters the risk profile of falls from height on a building site. Especially relating to being struck by an object. Generally reducing working at height when site fitting windows from scaffolding levels, is welcomed to reduce the likelihood of a person or object falling.

GEN1 site fitted window processes have an inherent risk that windows could fall over when stacked/ placed or drop from height, for example through scaffold hop-ups to levels below. It is also recognised that lifting windows manually, as a two-man operation and walking these around scaffolding, or across uneven ground near a plot, does present a risk of operatives falling over or falling from height, where injury could be severe.

However, the benefit of less exposure to falling, is offset by the risk associated with being struck by a falling object. As GEN3 is a crane erect system, there is an inherent risk from lifting overhead, a window pre-fitted within a wall panel. It could arise that a window may fall out of a panel dropped during crane lifting and placement. The severity of injury is significant in the event a heavy object was to inadvertently fall, no matter how unlikely this may be.

This risk is managed by confirming to LOLER lifting operations, with a formal lift plan, appointed person, and lift supervisor on site. Typically, the use of a crane drives improved processes to manage the risk of dropping or falling objects from arising. It is recognised that whilst the GEN1 site fitted approach has increased likelihood, the severity is less. The converse is the same for GEN3 factory fitted, hence the risk profile changes.

One important safety consideration, when factory fitting windows, is to ensure the MMC supplier within the factory has an audited system for ensuring the fixing of the window is correctly done, in the factory and that the fixing design, is such that it accommodates any short term loads and stresses that can arise during a lift or wind gust, that could result in a window dropping out of the panel. MMC suppliers whom factory fit windows often have additional control system including sign-off by supervisor and safety tagging of safety critical fixings such as factory fitted windows.

7.9. Slips and Trips

GEN3 factory fitted windows eliminates exposure to slips and trips on the site, associated with site stored and fitted windows. Generally, this is welcome safety benefit in the eyes of constructors. The factory fitting of windows removes all potential for pallets, packaging, and window components to be stored at ground level or on scaffolds, which present a risk from trips and slips. Factory fitted windows improves housekeeping reducing component quantity, storage needs and freeing up space to provide clearer access to plots. They are fitted in the final vertical position eliminating the risk of slips and trips.

GEN1 processes have an inherent risk that operatives could slip or fall when lifting windows manually as a two-man operation and walking these around scaffolding or across uneven ground does present a risk of operatives falling from height or falling over, where injury could be severe.

Displacing windows to be factory fitted, may not provide a nett H&S gain, by reducing slips and trips from a holistic perspective. It is recognised that receiving, storing, and handling windows in a factory can also give rise to slips and trips safety issues. However, there is potential to mitigate these by introducing safety control systems within the factory environment.

All factory offloading and distribution of windows is done on a flat level hardstanding, using trained and component forklift drivers. The storage of windows is simplified by using a-frame or pallet handling systems and internal suitable storage racks or laydown locations. All material flows are well managed from receipt, handling, and distribution to production, by multiple in house qualified and skilled warehouse operatives, supervisors, and managers. Most MMC producers will have in-house safety practitioners and will employ some form of Safety observation system and good practise housekeeping operations to reduce slips and trips from arising within the factory.

Figure 21. ***GEN1 Site Fitted Environment***

Figure 22. ***GEN3 Factory Fitted Environment***

7.10. High Impact Events - Plant Overturn

GEN3 factory fitted windows can be assumed to remove some forklift truck overturn risks that are associated with lifting windows to a first-floor landing platform. This would be in proportion to the reduced number of on-site pallets moved to such a platform. These are transferred to the overturn risks associated with increased risk associated with crane operations.

7.11. High Impact Events - Lifting Operations

GEN3 factory fitted windows require a crane to lift and place wall panel with windows pre-fitted. This changes the safety hierarchy on the site. Lift day is more important and requires robust lifting operational control systems to be in place. As a minimum this will require full compliance with a LOLER appointed person, and a lift supervisor physically on site. Lift day drives enhanced safety behaviours that are considered good practise, e.g. ensuring activities are well planned and that nearby activities and staff are engaged, aware and pre-warned, fostering a proactive approach to safety planning and execution.

The likelihood of a crane overturn or hazard arising from lifting operations is rare, but the impact of this could be extremely high. This is converse to the GEN1 risk profile where the likelihood is higher but the impact is considered to be less severe. In summary, the GEN3 profile reflects the potential for a large one-off, high impact event arising, compared to GEN1 being small, regularly low impact events arising, but overtime can lead to high impact health related issues i.e., MSD.

Figure 23. ***Example Schedule of Common Lifts & Crane Risk Assessment***

Individual Floor Cassettes Lifting Arrangement A	External Wall Panels Lifting Arrangement B	Panel Packs (Multiple) Lifting Arrangement C
		
4 leg chains, 1t sacrificial slings	2 leg chains, 1t sacrificial slings	4 leg chains, 6m web slings
Maximum Weight - As lifting plan Maximum Radius - As lifting plan	Maximum Weight - As lifting plan Maximum Radius - As lifting plan	Maximum Weight - As lifting plan Maximum Radius - As lifting plan
PRE SLUNG IN FACTORY 1 tonne slings are pre fitted to the panels in the factory. Check the condition of the straps before lifting. Straps are sacrificial and must be cut and disposed of to the mixed waste skips.	**PRE SLUNG IN FACTORY** 1 tonne slings are pre fitted to the panels in the factory. Check the condition of the straps before lifting. Straps are sacrificial and must be cut and disposed of to the mixed waste skips.	**SINGLE BASKET LIFT** The slinger will use the orange draw strings to pull through the web slings and attach each end to the chain legs.

STEWART Milne GROUP

OH&S CONSTRUCTION RISK ASSESSMENT FORM — CRANE WORK

Activity: CRANE WORK										Risk Assessment No RA 083 SMTS UK	
Persons at Risk	Public	√	On Site Personnel	√	Off Site Personnel		Contractors	√	Others	√	Issued by Group HSE Date: 16/5/2019
Site Review											
Client:	SMHC S				Project:	Carnwadock					
Date:	16/5/2019				Assessed By:	Paddy Wright			Title: Construction Manager		
Job description Erection of cranes, their safe use including slinging and movement of loads (not including complex lifts such as more than one crane lifting together, or cranes using load enhancement attachments or cranes being repaired or maintained).											
People at risk Site workers, client's personnel, general public, young/old/infirm, visitors.											

Hazard	Initial Risk Rating	Best Practice	Residual Risk Rating	Action
Failure to plan lift	High	All lifting operations must be planned and a lifting plan prepared by a CPCS appointed Person in accordance with BS 7121 and LOLER. Either full Contract lifts or if Managed OH&S SMC 27 Lifting Operations Lift Plan to be in place prior to any lifting operation be permitted.	Low	Lift Plan must be in place prior to any lift
Lightning strike, Severe Weather	High	Crane to be taken out of service at all times of threat and personnel removed from the area. Crane to have a functioning anemometer. Use the crane within the operators guidance for wind speeds etc.	Low	Crane not to be used in severe weather

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7.12. Future Factory Automation & Robotics

As the market matures for MMC systems and factory fitted window elements becomes an increasingly attractive commercial, safety and construction benefit the MMC supply chain needs to develop future solutions which overcomes the safety risk displacement welcomed by constructors, so that there is a net gain in overall safety improvement across the entire construction and manufacturing sector.

Increasingly, MMC suppliers are looking towards investing in technology to reduce labour dependency within the shop floor and improve productivity. This has been evident within the automotive sector. This learning can be transferred to the MMC sector to bring about industrialised change within the sector that overtime delivers a net safety gain to the community. Technologies used and being explored by some MMC suppliers include assisted vacuum lifting/placement and robotic placement/fixing of window elements.

Figure 24. ***Examples: Factory Mechanical Lifting systems, Automation & Robotics***

7.13. Management Arrangements

A key consideration is the fundamental shift in focus, of pre-construction management activities, to suit the GEN3 factory fitted window method. This requires a design for manufacture and assembly approach (DFMA). Its fundamental the MMC supplier/installer is involved early in this process. This is critical to ensure efficient, successful, and safe delivery of the project.

- Pre-Construction Phase: The GEN3 factory fitted window method requires additional health and safety management arrangements regarding the use of a crane and displacement of risk to the MMC factory environment. More planning, coordination and design considerations are needed early in the process to ensure windows arrive at the factory, are properly installed and installation of the wall panels with pre-fitted windows are fully considered as part of the site CDM safety plan
- Construction Phase: The upfront GEN3 factory fitted window benefit will be proportionately offset, by the reduced site-based planning, co-ordination, management, installation, and monitoring, needed for site fitted windows.

7.14. Conclusions: Site Fitted vs Factory Fitted Windows

The use of factory fitted windows reduces associated H&S risks/hazards on the building site, in the eyes of the constructor. This approach also changes the risk profile on the site, by removing many lesser risks, but introduces a few high impact risks. This shift in risk profile requires constructors to have early engagement with MMC suppliers/installers, to ensure the safety benefits and differing design and planning approaches are fully managed early in the DFMA and pre-construction safety planning stages.

However, it is important to realise that some risk is displaced to the MMC supplier's factory environment. It is therefore important to ensure that the net safety gain is fully achieved by ensuring the safety systems in the factory environment are managed more effectively than they can be on site.

Longer term, further hazards can be eliminated by MMC suppliers investing in automation and robotics, to reduce the manual working and handling practises that are meantime common within MMC factory facilities.

Further safety benefits can arise when the MMC supply chain develop a wider range of pre-fitted components including external and patio/French doors, where weight is increasingly becoming a more limiting factor on site.

8. OVERALL SUMMARY

This work package assessed differing H&S risk profile, when using panelised MMC systems. The focus was on assessing the difference between timber frame MMC systems, built using a forklift and manual assembly techniques (GEN1) and timber frame MMC systems, built with the assistance of a crane and higher levels of prefabrication (GEN3).

Deep dive H&S risk profiling assessments were undertaken on the following build techniques, each designed to increase the level of offsite prefabrication and simplify construction assembly on site. These were:

1. GEN1 forklift & loose joists v GEN3 crane & floor cassettes
2. GEN1 forklift & site fitted windows v GEN3 crane & pre-fitted windows

These two areas examined in detail the safety requirements and risk profiles associated with the differing techniques and working practises. AIMCH partners have built several homes using both techniques to prove the case for scaling up, using higher levels of panelised MMC prefabrication, in a progressive way. AIMCH focus is on building a weatherproof, insulated, and secure structural shell in one day, ideally with no scaffolding and a pre-tiled roof. This requires the use of a crane and the scaling up of current and future panelised MMC solutions.

Next Steps

AIMCH ambition is through the creation and exploitation of future industrialised housing techniques, such as panelised MMC building systems, that are safer and more productive, AIMCH will deliver more high quality, functional and appealing homes, safely and at an affordable cost.

9. CONCLUSIONS

The work provided detailed insights of the differing risk profiles when increasing the extent of prefabrication (PMV) used within Category 2 Timber Based MMC systems. When seeking to adopt MMC floor cassette and factory fitted windows utilising crane installation, two key conclusions emerged:

1. Advanced MMC can reduce risk exposure on-site by 20%, with a changed risk profile compared with more traditional methods – It is concluded that GEN3 crane erect advanced MMC systems can provide a generally safer onsite working environment, although the H&S risk profile differs from traditional systems. This is because many smaller, more frequent, and lower impact risks, that over time can lead to health issues, such as MSD (musculoskeletal disorders), are reduced or eliminated in GEN3. However, there is an increase in risk of very low likelihood, but high impact safety events., due to the use of a crane for heavy lifting operations. Cranes are not uncommon, but as the use of advanced MMC increases, this will become an increasing safety consideration with stringent management requirements.

2. Some risks associated with advanced MMC methods are displaced to MMC factory – There is a transfer of some safety risks from the construction site to the factory environment. Whilst this is beneficial to constructors, it is recognised that the MMC supply chain must drive safe factory operations to ensure that there is no net increase in risk for more advanced MMC-built homes. Risks can be effectively mitigated and controlled within the factory environment, where workplace safety systems are generally well managed. Many MMC suppliers are investing in safer and more productive factory techniques that eliminate manual working hazards, through introducing mechanical handling, automation, and robotic applications, as well as through standardisation of processes and components. Hence, in order that transfer of risk to the factory does not lead to an abdication of risk management, the procurers of MMC systems must ensure that effective controls are put in place so that an overall net safety gain is realised for the good of the sector.

10. RECOMMENDATIONS

1. This report to be made available on the AIMCH website for public dissemination
2. The conclusions in this report to be reviewed if appropriate following the completion of the analysis of time spent on-site for various activities, comparing traditional and MMC-built homes. This analysis is being carried out within the AIMCH project by Barratt and L&Q.
3. Key actors in the sector to evaluate whether a study should be carried out to develop benchmarks of risk for differing construction methods.

11. REFERENCES

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12. REVISIONS

Table 4. ***Record of changes to this document***

Name	Date	Version	Reason for issue	Changes
Stewart Dalgarno	22-Dec-2021	1.1	First draft for review	
Tim Limberger	26-Jan-2022	1.2	Amendments to risk tables and some of the report text	Throughout the report
Tim Limberger	24-Feb-2022	1.3	Further edits and refinement of the risk exposure method. Added references.	Throughout the report
Tim Limberger	10-Mar-2022	1.4	Minor edits and added links to HSE website sources	Throughout the report
Tim Limberger	10-Mar-2022	1.5	Rename report	Changed to “Health and Safety Risk Profiling of MMC Solutions”

13. APPENDICES

APPENDIX 1. SMTS GEN1 – GEN3 MMC TIMBER FRAME CLASSIFICATIONS

	STEWART Milne GROUP — OSM Gen 3 Timber Frame Build System	GEN 1 Housing — Build out on existing sites/phases	GEN 2 Apartments — All Live Apartments Projects	GEN 3 Housing — 6 x Trial Sites Currently Committed	GEN 3A Housing — New Sites starting after 31/10/2019	GEN 3B Housing — New Sites starting after 31/12/2020
Forklift Erect	Wind & Watertight in 5 - 10 days (Housing) or 3-4 weeks (Apartments)	X	X			
	Manually Erected	X	X			
	3 sided scaffold, open front & follow on adaptions	X				
	Manually placed wall panels	X	X			
	Small format walls limited to 115 kg weight	X	X			
	Safety deck system - floors & roofs	X				
	Loose joists, ironmogery and blocking site fitted off safety deck	X				
	Forklift and scaffolder permananetly on attendence	X				
	Forklift offloading, handling and feed to plot, through dropped front scaffold	X				
	Site fitted windows & french doors	X	X			
	Oxford trellis stairwell safety infill system - site fitted	X				
	Flooring site fitted	X				
	Roofs erected at Upper wall head off safety deck	X	X			
	Plasterboard manually loaded in, after kit erected	X	X			
	Party wall spandrels boarded on site at high level	X	X			
	Roofs felted and battened at high level	X	X			
	UPVC Fascia, barge, soffit and bootends at high level	X	X			
	Build - Sequential from DPC upwards	X	X			
	Attic trusses - Kellingside, Merrington & Longrush (Crane loaded, manually erected off safety deck at wall head)	X	NA			
	Raise Tie Trusses & Purlins - Comrie & Moor Coach home (Crane loaded & manually erected off safety deck)	X	NA			
Crane Erect	Wind & Watertight in ONE day			X	X	X
	Craned Erected		X	X	X	X
	4 sided scaffold & no adaptions - one hit strategy (excluding hop-ups)		X	X	X	X
	Manually placed wall panels		X	X		
	Small format walls limited to 115 kg weight		X	X		
	Crane placed wall panels		X		X	X
	Large format walls un-limited weight, up to 6m max.		X		X	X
	No Safety deck system, at floor or roof level		Roof Only	X	X	X
	Prefinished floor cassettes - joists, flooring, protection all prefabicated		OSB cassettes	X	X	X
	Crane offloading, handling and feed to plot, over scaffold		X	X	X	X
	One crane day - Lift & build sequence operations planned in advance		Multiple Lifts	X	X	X
	Forklift on attendence for roof on ground			X	X	X
	Site fitted windows & french doors			X		
	Factory fitted windows & french doors		X		X	X
	Prefitted - stairwell safety infill panels (removable)			X	X	X
	Taped & screwed floor cassettes joints, site fitted		Floating Floor	X	X	X
	Roofs erected at ground level off plot slab, prior to kit			X	X	X
	Plasterboard crane loaded in, during kit erection		X	X	X	X
	Preclad Party wall spandrels, erected at ground level as part roof carcass		X - Roof Level	X	X	X
	Roofs felted and battened at Ground level			X	X	X
	UPVC Fascia & barge fitted at Ground level			X	X	X
	UPVC soffit and bootends fitted at High level, off scaffold			X	X	X
	Build - Roof carcass, felt & batten, UPVC, crane & kit arrives, lift out, kit to wall head & roof placed			X	X	X
	Attic trusses - Kellingside, Merrington & Longrush (Crane loaded, manually erected off safety deck at wall head)		NA	X	X	
	Roof cassettes & purlins - Kellingside, Merrington & Longrush (Crane erected, no safety deck)		NA			X
	Raise Tie Trusses & Purlins - Comrie & Moor Coach home (Crane loaded & manually erected off safety deck)		NA	X	X	X
Note : As part of Woodlands W22 Range Rationalisation - Kellingside, Merrington & Comrie likely to be dropped						

APPENDIX 2. SMTS GEN3 TIMBER FRAME MMC BUILDING SYSTEM

Overall Build Programme Benefit													Number of Units	Number of Available Weeks	Build Rate per Week
Months	1	2	3	4	5	6	7	8	9	10	11	12			
GEN1	Overall Build Period = 12 months												50	50	1.00
	Substructures				Superstructures				Fit out & Cladding						
GEN3	Overall Build Period = 11 months												50	46	1.09
	Substructures				Superstructures				Fit out & Cladding						

One Month Saving in Wind & Watertight GEN3

One Month Overall Site Build Saving

GEN3 System Benefits

- Wind & watertight in a day
- Internal & external works can commence immediately after lift day
- Stair access immediately after timber frame erected
- All heavy items fitted or in place within home, ready to use
- Tidy presentable site, with free movement of traffic, after lift day
- No kit stored on site/plot/compound
- No safety deck to erect/dismantle/move and check/supervise
- Customer can walk through home (if desired)
- Smaller forklift, no need to forklift timber frame elements, with long toes
- Forklift freed up for other things
- Less damage and delay due to weather or material delays
- Less dependent on skilled erectors & manual working
- Site working practise much improved
- Reduced manual handling, working at height, material handling and site traffic
- Commercially competitive
- Improved construction predictability & programme reliability
- Reduces overall build programme, saving prelim costs
- Provides capacity to erect two timber frame per week
- Improves front end work planning, site organisation and thinking





APPENDIX 3. CONSTRUCTION INDUSTRY RISK PROFILE AREAS (IRP) – SEE REF (5)

Industry Risk Profile (IRP) Category		Description of IRP Category	In scope
1	Asbestos	Includes all risks arising from exposure to asbestos	N
2	Burns from hot substances/ surfaces	Burns from hot steam, gases, liquids, tars or other hot substance or surface	N
3	Chemical harm, irritant or corrosive	Harm through contact with chemical	N
4	Confined Spaces	Risks arising from entry into confined spaces, including from CO asphyxiation arising from use of gas appliances in site porta cabins or similar.	N
5	Crushed by excavation	Risks arising where an excavation or part of an excavation collapses.	N
6	Electric shock	Risks arising from contact with electricity	N
7	Fall from Ladder	Includes risks of falling rom ladders or stepladders, when being used for access or to work from.	N
8	Fall from open edge	A broad category that includes risks of falling from any open edge. Includes mezzanine floors, unprotected slab edges, lift shafts, roof edges etc.	Y
9	Fall from Scaffold	Includes risks of falling from any kind of scaffold, fixed, tower or system type. Including falls when erecting or dismantling.	Y
10	Fall through fragile material	Includes risks of falling through fragile roof or ceiling material, including asbestos cement sheets or perspex rooflights.	N
11	Fire/explosion	Risks arising from fire or explosion	N
12	Lead	Risks arising from exposure to Lead	N
13	Machinery guarding	Includes risk of contact or entanglement where a main cause is a lack of machine guarding.	Y
14	Materials Handling inc. Manual handling	Includes all risks arising from persons lifting, carrying or moving materials, including while unloading vehicles, and whilst carrying objects, individually or as part of a team lift.	Y
15	Mechanical Lifting Operations	Risks arising where an object is being lifted by a crane or hoist, and there is a loss of control, overturn, breakage or similar. Includes objects dropped whilst being lifted	Y
16	MEWP Operations	Includes risks of entrapment by a MEWP or fall from a MEWP, whilst working at height	N
17	Noise	Includes all risks arising from excessive noise	Y
18	Other hazardous dust	Risks arising from inhalation of general building dust generated by construction work activities	N
19	Overturning plant or moving machinery	Includes all risks arising from incidents where plant, e.g. dumpers or excavators overturn, often caused by slopes or excessive speed. Includes MEWPS operating in transport mode, and other relevant classes of machinery	N
20	Public protection	Where members of the Public are exposed to danger, includes risks to children	N
21	Silica dust	Risks arising from inhalation of silica dust	N
22	Slip or trip on same level	Risks arising from trip hazards, slippery floors, poor design steps, projecting nails	Y
23	Struck by a falling object	Risks of being struck by a falling object, from a height	Y

24	**Struck by flying object/dust/ material**	Struck by object, dust, material flying freely, by wind, ejection from machine etc	Y
25	**Struck by moving vehicle**	Includes reversing and slow-moving vehicles, remote controlled or on rails. Includes MEWPS not working at height. Includes risks arising from lack of segregation with pedestrians	Y
26	**Unintended collapse**	Unintended collapse of a structure or part of a structure, or temporary works intended to aid construction of a structure	Y
27	**Using hand/power tools**	Includes risks arising from operation of hand tools, power tools and up to pedestrian operated plant, such as wacker plates or road roller.	Y
28	**Vibration**	Includes all risks arising from exposure to hand, arm or whole body vibration	Y
29	**Welfare**	Risks arising from a failure to comply with Schedule 2 of CDM	N
30	**Wood dust**	Risks arising from inhalation of wood dust	Y
31	**OTHER**		Y

APPENDIX 4. RISK ASSESSMENT PROCESS

This assessment was based on a typical risk assessment approach, but with some changes to focus it on risk exposure rather than probability and to assess impact against RIDDOR reportable event classifications.

1. Assess Risk Exposure

Risk Exposure level	Exposure time, e.g. hrs pw exposed to the potential risk
VH	>30 hrs
H	15-30 hrs
M	5-15 hrs
L	1-5 hrs
VL	<1 hr

2. Assess Risk Impact

Impact level	Worst case impact	RIDDOR reportable
VH	Death	Y
H	Specified injuries	Y
M	>7-day incapacitation	Y
L	>3-day incapacitation	Y
VL	Non-reportable	N

3. Calculate total risk exposure using the risk scoring scheme "look-up table"

Exposure	Hrs pw		Risk assessment		Overall risk score: risk exposure				
Majority of time	>30 hrs	Probability	Very High	VH	9	14	19	24	29
Routine	15-30 hrs		High	H	7	12	17	22	27
Frequent	5-15 hrs		Medium	M	5	10	15	20	25
Occasional	1-5 hrs		Low	L	3	8	13	18	23
Very limited	<1 hr		Very Low	VL	1	6	11	16	21
					VL	L	M	H	VH
					Very Low	Low	Medium	High	Very High
					Impact				
				Health & Safety	Non-reportable	>3 day incapacitation	>7 day incapacitation	Specified injuries	Death
						RIDDOR reportable			

APPENDIX 5. H&S RISK ASSESSMENT FOR CASE STUDY 1: LOOSE JOISTS VS MMC FLOOR CASSETTES

Note: these risk assessments are the judgements of the authors, and are not based on numerate data, which was not available for this study. The judgements were based on perception of the amount of time spent on the activities and the possible worst-case impact of an event. Further supporting evidence may be provided in future analysis of the time spent on-site for various activities, comparing traditional and MMC-built homes.

IRP ID	Risk types		GEN1 risk assessment			GEN3 risk assessment		
	Risk grouping	Risk title	Exposure (hrs pw)	Impact	Risk score	Exposure (hrs pw)	Impact	Risk score
8	Falls	Fall from open edge	L	H	18	L	H	18
9	Falls	Fall from Scaffold	M	H	20	L	H	18
13	Machines	Machinery guarding	VH	H	24	L	H	18
14	Handling and Lifting	Materials Handling inc. Manual handling	VH	L	14	L	L	8
15	Handling and Lifting	Mechanical Lifting Operations	H	VH	27	M	VH	25
17	Noise and Vibration	Noise	VH	L	14	L	L	8
22	Slips and trip	Slip or trip on same level	VH	L	14	L	L	8
23	Collisions	Struck by a falling object	H	VH	27	M	VH	25
24	Collisions	Struck by flying object/ dust/ material	H	M	17	VL	M	11
25	Collisions	Struck by moving vehicle	H	H	22	M	H	20
26	Collapse	Unintended collapse	M	H	20	L	H	18
27	Machines	Using hand/power tools	VH	H	24	M	H	20
28	Noise and Vibration	Vibration	VH	L	14	M	L	10
30	Respiratory	Wood dust	VH	M	19	VL	M	11
31	Other	OTHER	M	L	10	L	L	8
Loose joists vs MMC cassettes		**TOTAL**	**GEN1 loose joists**		**284**	**GEN3 MMC cassettes**		**226**

APPENDIX 6. H&S RISK ASSESSMENT FOR CASE STUDY 2: SITE FITTED VS FACTORY FITTED WINDOWS

Note: these risk assessments are the judgements of the authors, and are not based on numerate data, which was not available for this study. The judgements were based on perception of the amount of time spent on the activities and the possible worst-case impact of an event. Further supporting evidence may be provided in future analysis of the time spent on-site for various activities, comparing traditional and MMC-built homes.

IRP ID	Risk types		GEN1 risk assessment			GEN3 risk assessment		
	Risk grouping	Risk title	Exposure (hrs pw)	Impact	Risk score	Exposure (hrs pw)	Impact	Risk score
8	Falls	Fall from open edge	H	H	22	L	H	18
9	Falls	Fall from Scaffold	H	H	22	L	H	18
13	Machines	Machinery guarding	VH	H	24	L	H	18
14	Handling and Lifting	Materials Handling inc. Manual handling	VH	L	14	L	L	8
15	Handling and Lifting	Mechanical Lifting Operations	M	VH	25	M	VH	25
17	Noise and Vibration	Noise	M	L	10	L	L	8
22	Slips and trip	Slip or trip on same level	VH	L	14	L	L	8
23	Collisions	Struck by a falling object	H	VH	27	M	VH	25
24	Collisions	Struck by flying object/ dust/ material	H	M	17	VL	M	11
25	Collisions	Struck by moving vehicle	H	H	22	M	H	20
26	Collapse	Unintended collapse	M	H	20	M	H	20
27	Machines	Using hand/power tools	VH	H	24	M	H	20
28	Noise and Vibration	Vibration	VH	L	14	M	L	10
30	Respiratory	Wood dust	M	L	10	VL	L	6
31	Other	OTHER						
Site fitted windows vs FFW		**TOTAL**	**GEN1 site fitted windows**		**265**	**GEN3 FFW**		**215**

APPENDIX 7. H&S RISK ASSESSMENT CATEGORY GROUPINGS

From Appendix 3, the in-scope risks were grouped as follows for the purpose of risk assessment and charting

Risk No.	Risk grouping	IRP category
8	Falls	Fall from open edge
9	Falls	Fall from Scaffold
13	Machines	Machinery guarding
14	Handling and Lifting	Materials Handling inc. Manual handling
15	Handling and Lifting	Mechanical Lifting Operations
17	Noise and Vibration	Noise
22	Slips and trip	Slip or trip on same level
23	Collisions	Struck by a falling object
24	Collisions	Struck by flying object/ dust/ material
25	Collisions	Struck by moving vehicle
26	Collapse	Unintended collapse
27	Machines	Using hand/power tools
28	Noise and Vibration	Vibration
30	Respiratory	Wood dust
31	Other	OTHER

APPENDIX 8. TOTAL H&S RISK EXPOSURE IN RISK GROUPINGS FOR CASE STUDY 1 AND 2 AND GEN1 VS GEN3

HSE IRP grouping	CASE STUDY 1		CASE STUDY 2	
	GEN1 Loose joists	GEN3 MMC floor cassettes	GEN1 Site-fitted windows	GEN3 MMC FFW
Collapse	20	18	20	20
Collisions	66	56	66	56
Falls	38	36	44	36
Handling & Lifting	41	33	39	33
Machines	48	38	48	38
Noise & Vibration	28	18	24	18
Other	10	8	0	0
Respiratory	19	11	10	6
Slips & Trips	14	8	14	8
TOTAL RISK EXPOSURE	**284**	**226**	**265**	**215**
Reduction in on-site risk exposure: GEN1 to GEN3	**-20%**		**-19%**	

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