Lahouti, Ali; Maybee, Don (2021) QwikInstall: Justified-for-Time Delivery, and Installation of a Hollow Metal Door Frame System. *Lean Construction Journal* 2021 pp 18-35 (submitted 18Nov2020; Accepted 27Jan2021)
www.leanconstructionjournal.org

Qwikinstall: Justified-for-Time Delivery, and Installation of a Hollow Metal Door Frame System

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Abstract

Question: How will a *Qwikinstall* system impact and improve the installation process of a metal door frame?

Purpose: This case study presents benefits a *Qwikinstall* metal door frame system delivers to construction operations performance.

Research Method: Experimentation; observation; and work sampling

Findings: A *Qwikinstall* system releases dependencies between construction of a wall framing and installation of a hollow metal door frame; It enhances ease of installation, maintains work flow, reduces re-work, and improves schedule performance for installation of door frames, as well as gypsum (drywall) boards placement.

Limitations: Experimentation of the *Qwikinstall* metal door frame system was conducted in a controlled environment.

Implications: The *Qwikinstall* system reduces waste in installation process of a metal door frame, and placement of its surrounding gypsum (drywall) boards.

Value for authors: Overcoming challenges of testing a custom-made system. Sharing findings of the *Qwikinstall* metal door frame system.

Keywords: Justified-for-Time; Just-in-Time; Work Structuring; *Qwikinstall* Metal Door Frame; Welded Hollow Metal Door Frame; Knock-down Metal Door Frame

Paper type: Case study

Introduction

One of the foundation of the Lean Thinking philosophy is reliability in flow of work – to be achieved by minimization of the eight categories of wastes (Koskela, Bølviken, & Rooke, 2013), namely: Defect; Overproduction; Waiting; Not Utilizing People's Skills; Transportation; Inventory; Motion; and Excessive Processing.

To date, numerous methods have been introduced as "Lean" tools for: identifying waste whether in operation or in process; analyzing its root causes; and eliminating it.

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Among these is Just-in-Time (JIT) – a strategy for elimination and/or minimization of waste in (construction, among others) operations (and perhaps processes).

At its core, Just-in-Time (JIT) is based on “having the right items of the right quality and quantity in the right place and at the right time” (Pheng & Hui, 1999). Examining the structure of Just-in-Time strategy (Table 1) reveals how it attacks two categories of wastes: defect – e.g., rework; correction; and waiting – e.g., walking without working; workers waiting for work; work waiting for workers. The “right items of the right quality” eliminates defect; the “right items of the right quantity at the right place” reduces waiting; and the “right place” potentially reduces defect and minimizes waiting.

Table 1: Impact of Just-in-Time Planning Strategy on Waste Management

Characteristics of Just-in-Time	Primary Impact on Waste Management
the right items	defect; rework; correction
the right quality	defect; rework; correction
the right quantity	waiting; waiting for work
the right place	waiting; waiting for work
the right time	waiting; waiting for work

Advantages of Just-in-Time planning approach promise a continuous, and more reliable flow of work – for particularly a considerable portion of building materials are often fabricated off-construction sites for installation (Opfer, 1998). A welded hollow metal door frame (WHMDF) is a typical example of building materials which is fabricated elsewhere for installation on a construction job site.

Welded hollow metal door frames (WHMDF) are fabricated in accordance with schedules of Architectural Finishes to fit customized or standard wall openings.

The installation process of a WHMDF typically follows three different sequences with respect to construction of its surrounding wall structure:

- Before construction of a wall
- During construction of a wall
- After construction of a wall

Any one of these sequences may offer an advantage over another. Installation of a WHMDF before or during constructing its surrounding wall is deemed to accommodate ease of installation as a workable opening for placement of a door frame after construction of a wall may be a challenge. Installing WHMDF before or after constructing walls allows for an uninterrupted flow of work. Installing it during wall construction will demand stop, set-up, and start.

The type of re-work necessary and its magnitude will also vary depending on whether a WHMDF is installed before, during, or after construction of the wall. To accommodate variations in availability and/or delivery schedule issues of supplies, installing a WHMDF after construction has been the go-to strategy. These +’s and Δ’s are summarized in Table 2.

Table 2: Interaction between Construction of Wall Framing and Installation of WHMDF

Welded Hollow Metal Door Frame Installation		Ease of Installation	Flow of Work	Re-Work	Schedule
	BEFORE constructing a wall	+	+	Δ	Δ
	DURING constructing a wall	+	Δ	Δ	Δ
	AFTER constructing a wall	Δ	+	Δ	+

Either of these three (aforementioned) sequences may uphold its just-in-time (or rather justified-for-time) state at the expense of some trade-offs:

- In "before"-sequence the flow of work criterion will be traded off with re-work, and schedule (i.e., time);
- Ease of installation in "during"-sequence is traded off for flow of work, re-work, and schedule;
- "After"-sequence trades off flow of work, and schedule for ease of installation, and re-work.

In general, sequencing priorities are governed by "Physical Relationships", "Interaction of construction trades", "interference-free path for all the objects", and/or "Code regulations" (Echeverry, Ibbs, & Kim, 1991) – where all are inherent of a construction project job site but the "Physical Relationship" which examines ways building components depends upon one another in a structure. Such physical dependency in case of a WHMDF exists between it and its surrounding wall framing; and unless such dependency to a wall framing is altered, just-in-time installation of a WHMDF will force trade-offs between flow of work, re-work, and/or schedule.

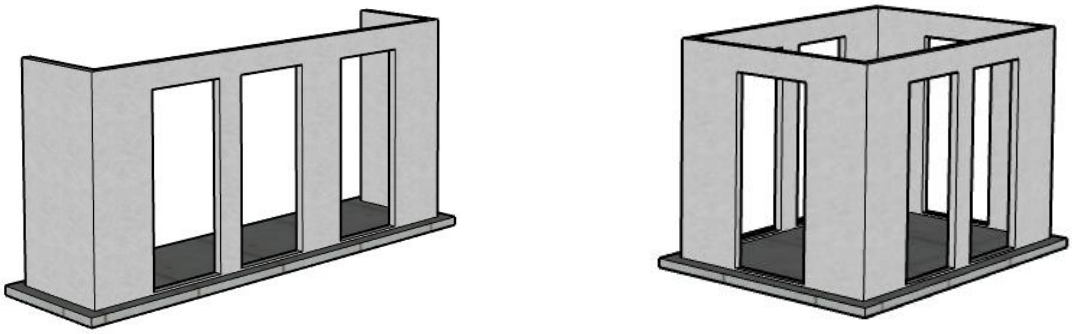
A "*Qwikinstall*" metal door frame alters that physical dependency of a door frame on its surrounding wall framing; and conveniently reinstates it between a door and a door frame as can be logically deduced, while still providing for a justified-for-time plan. The *Qwikinstall* is a hollow metal door frame composed of interlocking pieces with overall dimensions nearly comparable to traditional WHMDF which may be installed as soon as gypsum (drywall) boards are placed up to immediately before installation of a door (and its hardware).

To understand the practical implications imposed and/or opportunities offered by the Just-in-Time (or rather Justified-for-Time) placement of a *Qwikinstall* metal door frame, a series of experimentations were undertaken. A welded hollow metal door frame (i.e., Experiment I) and a *Qwikinstall* metal door frame (i.e., Experiment II) were placed <u>after</u> their surrounding wall structures were framed.

Experimentation

The experimentations were conducted with voluntary participation of three construction General Contractors. Each experiment was set up for installation of three (3)

3070 (i.e., 3' × 7' or 36" × 84") door frames, and placement of their surrounding drywall boards by skilled trades professional in two layouts illustrated in Figure 1. Durations of activities were measured in each experiment, and the work was sampled in intervals of 15 seconds. Constraints in availability of resources (e.g., space; and labor/person-power) mandated one construction General Contractor to conduct the experiment differently with regards to experimentation layout, and another with regards to crew-size assigned for experimentation. This information is reported in Table 3 and Table 4.



(a) (b)

Figure 1. Experimentation Layout

Welded Hollow Metal Door Frame (WHMDF)

In a common, and (as skilled trades professionals wish to call) straight-forward practice of installation, the WHMDF with wood-stud wrapping anchors is placed into the center of an unfinished 18-gauge steel-stud opening. Then, a leveled door frame is anchored to the floor – first the *jamb* side where floor elevation is the

greatest; and second the other jamb side. Last, the door frame *header* is fastened. It is important to note that no adjustment may be done after installation – for majority of WHMDF's are not of adjustable configurations.

Upon completed installation of the three (3) WHMDF, back and front sides of metal-stud wall framings were covered with gypsum (drywall) boards. Table 3 summarizes the installation activity performance for three experiments.

Table 3: WHMDF and Gypsum (Drywall) Board Installation Productivity

construction general contractor	layout	WHMDF			Drywall Board		
		crew size	number of unit	operation time	crew size	surface area	operation time
volunteer **A**	(b)	2	3	16.50 minutes	2	320 sqft	35.00 minutes
volunteer **B**	(a)	2	3	34.50 minutes	2	272 sqft	134.50 minutes
volunteer **C**	(b)	1	3	27.50 minutes	2	320 sqft	40.50 minutes

Qwikinstall Metal Door Frame

Three main elements compose a *Qwikinstall* metal door frame: Mounting Plate; Active Frame; and Trim Frame. Figure 2 is a schematic illustration of an assembled *Qwikinstall* metal door frame.

The three main elements of *Qwikinstall* are secured (i.e., anchored, or screwed) in-place and/or on one another by following supporting components:

- Stud Locking Clips
- Mounting Studs
- Mounting Brackets
- Snap Locks
- Snap Lock Bridges

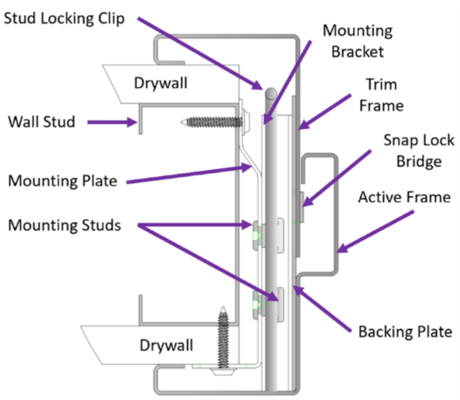


Figure 2. *Qwikinstall* Interlocking Components

In this experiment, first back and front sides of 18-gauge steel-stud wall framings surrounding the opening were covered with gypsum (drywall) boards. Then, at the (ideal) location of a finished wall opening two identical *Qwikinstall Mounting Plates* were installed on each side of the wall opening – first on the side where floor elevation is the highest. These plates, next, hosted the *Active Frame*. Last, a *Trim Frame* was seated on the *Active Frame*.

The activity performance for installation of *Qwikinstall* door frame and placement of gypsum (drywall) boards on its surrounding metal-stud framing is reported in Table 4.

Table 4: *Qwikinstall* Door Frame and Gypsum (Drywall) Board Installation Productivity

construction general contractor	layout	*Qwikinstall*			Drywall Board		
		crew size	number of unit	operation time	crew size	surface area	operation time
volunteer **A**	(b)	1	3	19 minutes	2	320 sqft	27.75 minutes
volunteer **B**	(a)	1	3	21 minutes	2	272 sqft	34.50 minutes
volunteer **C**	(b)	1	3	21 minutes	2	320 sqft	34.25 minutes

Discussion

▪ Ease of Installation

Illustrated in Figure 3, evaluation of activity total duration for these experimentations reveals improvement in performance from experimentation (I) to experimentation (II). "*Ease of Installation*" – or lack thereof – will comfortably validate such improvement – a specific instance of which is the event of Experimentation (I) for construction General Contractor B.

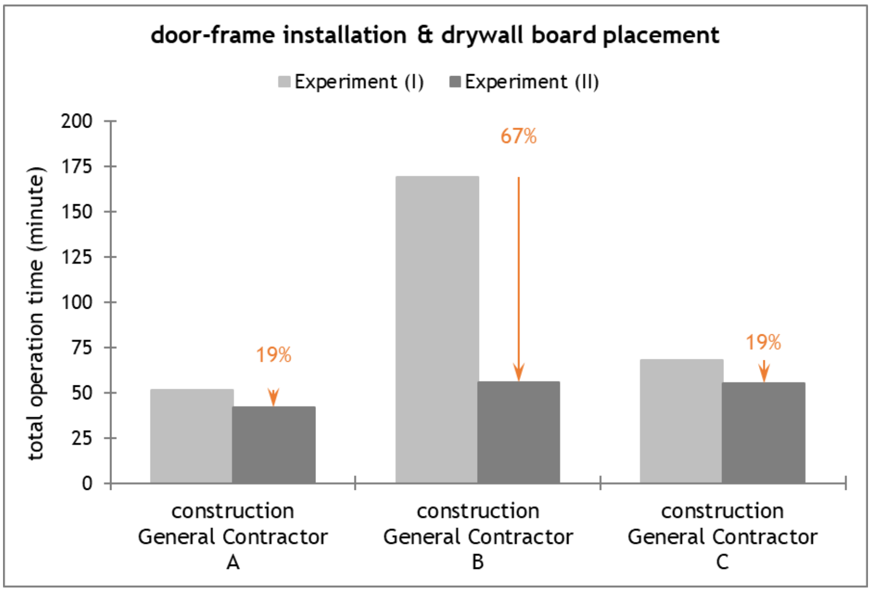


Figure 3. Activity Total Duration for Installation of Metal Door Frame and Placement of Surrounding Gypsum (Drywall) Boards

In Experiment (I), construction General Contractor B attempted to install a WHMDF manufactured with wood-stud wrapping anchors (Figure 4). Although a wrapping anchor is often suitable for a wood-stud wall framing, its use in steel-stud wall framing is common where wall-opening space is limited, and access to back side of a steel-stud is restricted. Each of this anchor type has two metal straps which are wrapped around a steel stud, and are screwed to it. This common, and straight-forward process of WHMDF installation demands excessive physical exertion. As was specifically observed in this very experiment, rough-carpentry skilled trade professionals had to frequently kneel on the concrete slab, and climb the ladder several times in process of installation – activities which would often introduce a greater likelihood of job-site accidents and occupational injuries.

"Ease of Installation" – or lack thereof – was validated not only in installation process of metal door frames but also in placement of their surrounding gypsum (drywall) boards. In this specific instance the thickness of the metal straps in addition to that of a pan-head screw narrowed the space available between WHMDF and steel studs as much so the required nominal (0.625 inches) clearance was not satisfied. As such, the thin opening could not host the thickness of a drywall board. Consequently, a non-value added, yet seemingly-necessary task was generated: shaving edges of the gypsum board to fit in the available space between the WHMDF and the steel stud.

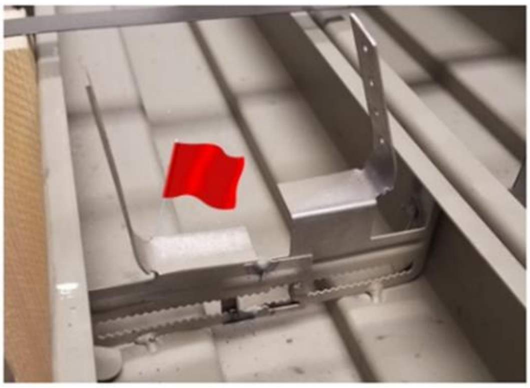


Figure 4. Typical Wrapping Anchor Welded on a Hollow Metal Door Frame

That was not the only issue: as summarized in Table 3, construction General Contractor B was assigned to layout (a) of Figure 1 for Experimentations (I), and (II). In that arrangement, wall-opening (2), and (3) are apart from one another slightly more than one foot. Placement of a gypsum (drywall) board in such narrow space translated into several attempts, and different placement strategies. The successful effort of placement is presented in Figure 5 – where one rough-carpentry skilled trade professional pried the opening between WHMDF and steel stud while the other one climbed a ladder to push down a drywall board. Such non-value added, and yet seemingly necessary task is often a typical event in the process of a WHMDF installation, and placement of its surroundings gypsum (drywall) boards. Temporarily securing the WHMDF in place to anchor, and "shimming" to control the space between a door frame and steel-stud are among common ones.

Figure 5. Drywall Placement Layout (a) in Experimentation (I)

Common observations in Experimentation (I) among construction General Contractors A, B, and C were frequent measuring (and re-measuring) activity in the installation of WHMDF to ensure it was centered in the wall opening, and was leveled at its bottom, and the top. Commonality of this observation extended to placement of gypsum (drywall) boards in which frequent measuring activity was necessary to make certain that fit pieces of drywall boards were cut. In the case of construction General Contractor B, ten (10) pieces of drywall boards (Figure 6) that covered steel-stud wall framings required countless measuring (and re-measuring), and numerous cutting.

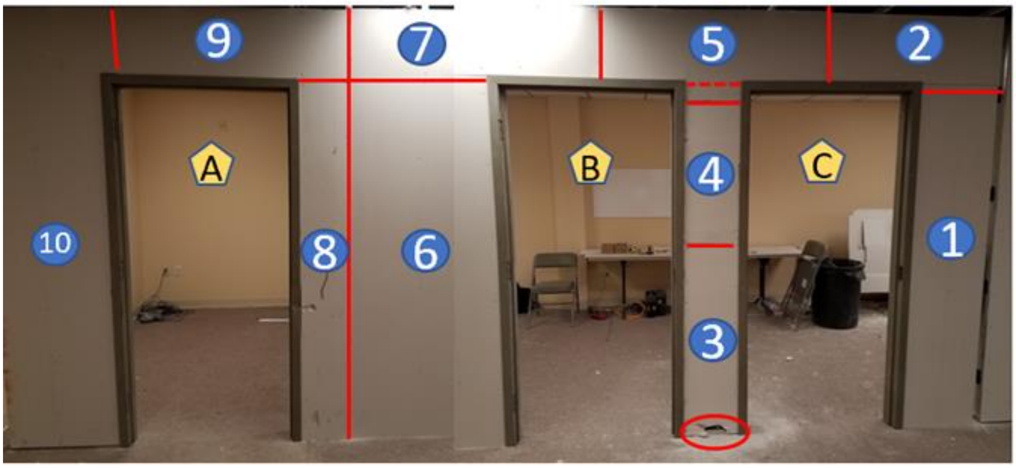


Figure 6. Front Elevation of Layout (a) in Experimentation (I)

Ease of installation, in its true meaning, was a predominant theme in the event of Experimentation (II) – whether construction General Contractors A, B, or C conducted the experimentation. An observer of the Experimentation (II) stated:

"Once the [drywall] boards were placed, the cuts were made for the [wall] openings with the steel studs acting as templates. Cuts were made at the edge of the stud with no need of measuring; And since the [*Qwikinstall* metal door] frame was installed after placement of the [drywall] boards, there was no need to fit pieces of various dimensions around the door frame. This sequence assured the drywall boards were positioned behind the metal door frame correctly, and in compliance with fire-rating requirements".

Figure 7 shows the layout (a) as an example.

Figure 7. Front Elevation of Layout (a) in Experimentation (II)

Qwikinstall metal door frame breaks the long-established, physical dependency of a (metal) door frame installation from its surrounding wall framing; and moves it to a (literally) convenient sequence in delivery and execution. Such relaxation in the sequence of activities not only translates into fewer cuts of gypsum (drywall) boards as shown in Figure 7, but also provided an uninterrupted flow of work in the process of placing gypsum (drywall) boards. As summarized in Figure 8, continuous workflow in turn improved the productivity in placement of gypsum (drywall) boards.

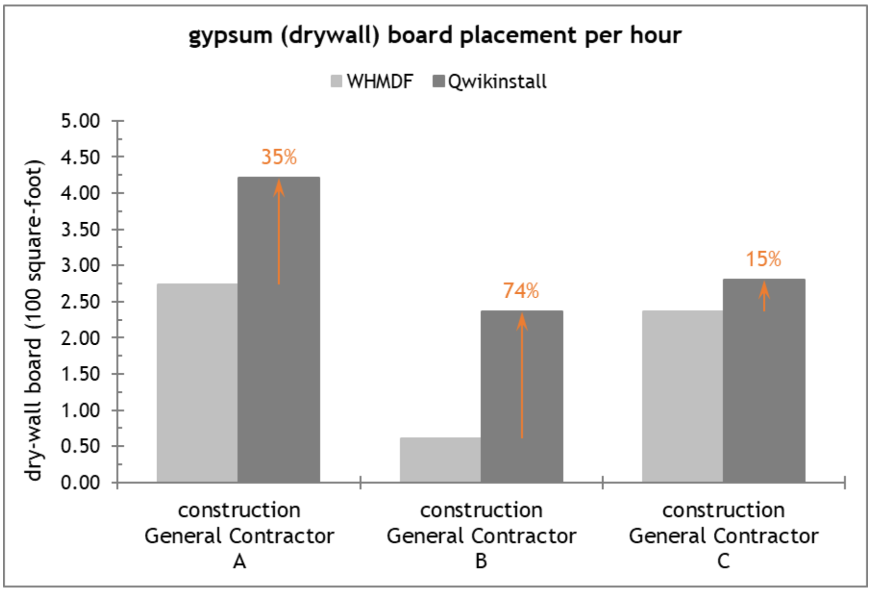


Figure 8. Activity Duration for Placement of Gypsum (Drywall) Boards

Ease of installation in case of *Qwikinstall* metal door frame manifested in need for fewer resources. As was reported in Table 4, a crew of one rough-carpentry skilled trade professional installed a *Qwikinstall* door frame comfortably and with minimal physical exertion (e.g., fewer kneeling). Such ease also delivered productivity improvement in terms of labor-hour – as Figure 9 summarizes – since several [non-value added] tasks (e.g., frequent measuring; changing tool; etc.) seemingly necessary in process of installing a WHMDF were eliminated in case of the *Qwikinstall* door frame.

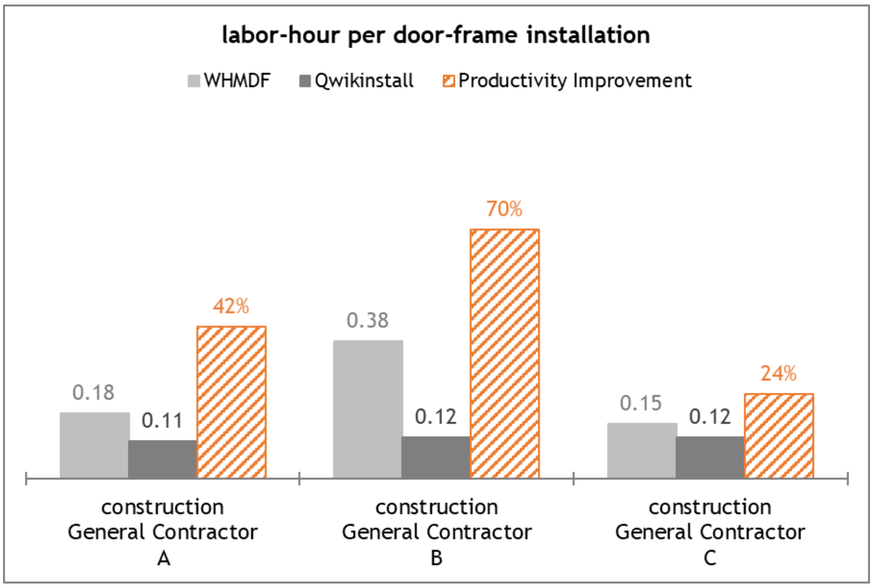


Figure 9. Productivity Performance of Door Frames Installation

It too is worth to note the improved productivity of gypsum (drywall) boards installation which, as may be gleaned from Figure 10, resulted from ease of installation – "too much time to fit drywall [boards]". It is a rathe time-consuming task to place a piece of drywall board behind a WHMDF where most likely the room for maneuver is limited; which in turn "may require making more pieces which require more butt-joints in the drywall" (Mastroianni, 2019).

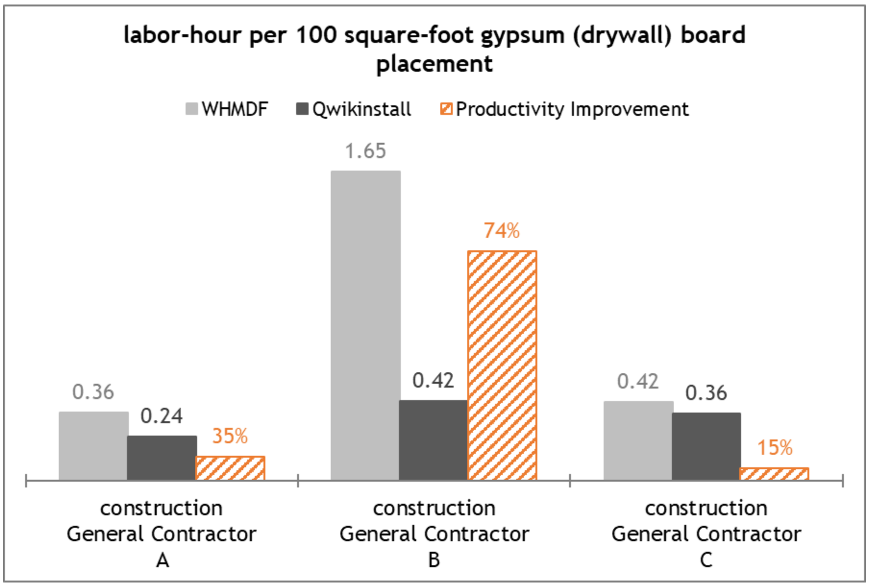


Figure 10. Productivity Performance of Gypsum (Drywall) Board Placement

▪ Flow of Work

The chain of value-added activities maintains an uninterrupted flow of work, and the more reliable workflow is, the better activity productivity performance will be. This very improvement in activity productivity – or lack thereof – was observed in the experimentations. As was previously stated, the entire work in these experimentations (i.e., metal doors frames installation, and gypsum boards placement) were sampled in 15-second intervals. Figure 11 reports population sizes for activities which construction General Contractors A, B, and C conducted in each of the experimentations.

While total number of activities conducted by construction General Contractor C for installation of three *Qwikinstall* metal door frames is almost as many as those for the installation of WHMDF's, the activity population for installation of a *Qwikinstall* metal door frame shrunk roughly in half (45%, and 63%, respectively) in comparison with those of WHMDF's by construction General Contractors A, and B.

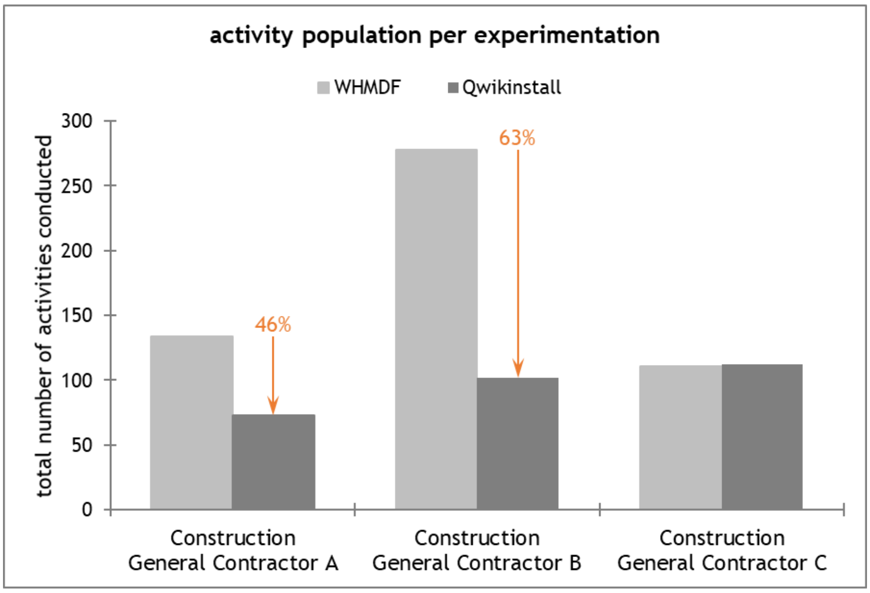


Figure 11. Number of Activities Conducted in each Experimentation

Improvements in total number of activities conducted may have resulted from the size of the crew used by the General Contractors A, and B – which was twice as many In installation of a WHMDF as it was in case of a *Qwikinstall* door frame (Table 3, and Table 4). The crew size of construction General Contractor C was unchanged between experimentations.

These observed activities were evaluated whether each would generate value. From the perspective of Lean-Thinking principles, an action in any process adds value if-and-only-if it:

- changes form, function, and/or shape of a product;
- is performed right the first time/is only handled once; and
- is a change/an improvement the customer is willing to pay for.

Table 5 summarizes categories of activity defined in these experimentations.

Table 5: Category of Activity in Work-Sampling

Necessary, & Value-added (N-VA)	Necessary, & Non-value-added (N-NVA)	Non-necessary, & Non-value-added (NN-NVA)
Assemble / Install	Adjust	Disassemble *
	Change Tools	Transport
	Cut (Material)	Wait
	Measure / Inspect	Walk
	Position (to assemble)	

* Disassemble was categorized as NN-NVA so long as it represented re-work.

Distribution of observed activities in a value stream spectrum are illustrated in Figure 12 and Figure 13 - where A, B, and C represent construction General Contractors A, B, and C, respectively.

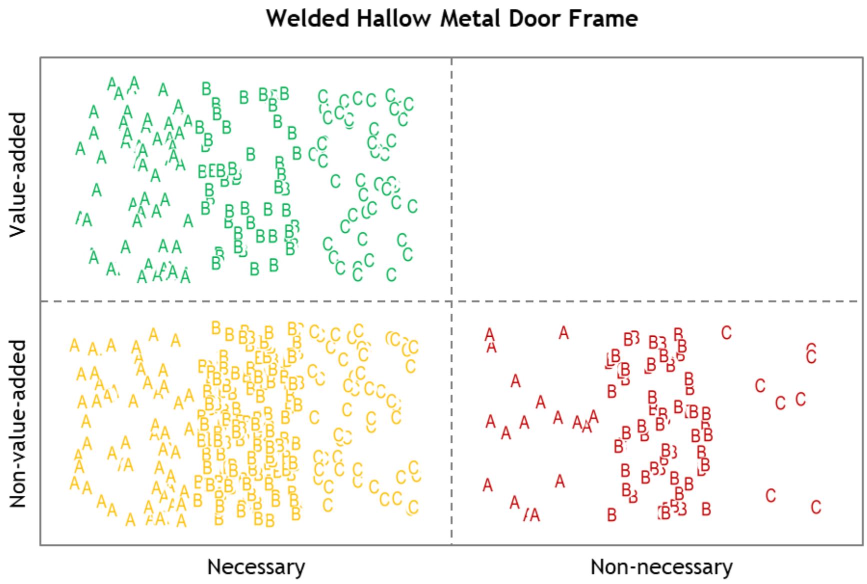


Figure 12. Value Stream Distribution of Activities – WHMDF

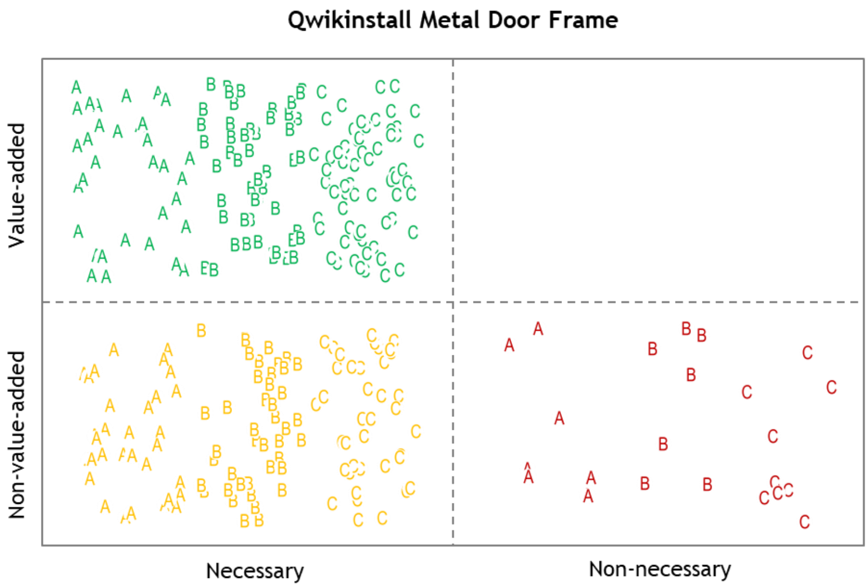


Figure 13. Value Stream Distribution of Activities - *Qwikinstall*

As the most prominent task of an improvement effort is to recognize, and eliminate waste, 24% (construction General Contractor A), and 69% (construction General Contractor B) of Non-necessary, Non-value-added (NN-NVA) activities were eliminated in process of *Qwikinstall* metal door frames installation while compared with installation process of a WHDMF. The portion of Non-necessary, Non-value-added (NN-NVA) activities population conducted by construction General Contractor C left almost unchanged between two experimentations.

After addressing the "lowest hanging fruit" (i.e., waste) in improvement management of a process, the Necessary, Non-value-added (N-NVA) activities come next.

As reported in Table 6, N-NVA activities in *Qwikinstall* experimentation accounted only for roughly two-third of that in WHMDF installation process – i.e., a 27% decrease in portions of activities conducted by construction General Contractors B, and C. The proportions of Necessary, Non-value-added (N-NVA) activities conducted by construction General Contactor C remained nearly unchanged between experimentations.

Table 6: Statistics of Value Stream Distribution between Experimentations

	Construction General Contractor A		Construction General Contractor B		Construction General Contractor C	
	WHMDF	*Qwikinstall*	WHMDF	*Qwikinstall*	WHMDF	*Qwikinstall*
Activity Population	134	74	278	102	111	112
		↓ 45%		**↓ 63%**		**~ 0%**
Necessary, & Value-added	43%	45%	20%	51%	44%	56%
		↑ 4%		**↑ 61%**		**↑ 22%**
Necessary, & Non-value-added	44%	45%	58%	42%	49%	36%
		~ 0%		**↓ 27%**		**↓ 27%**
Non-necessary, & Non-value-added	13%	10%	22%	7%	7%	8%
		↓ 24%		**↓ 69%**		**~ 0%**

- ## Re-Work

Non-necessary, non-value-added re-work refers to activities which are not performed right the first time, and are conducted to correct a consequent defect. The nature of welded hollow metal system of a door frame hosts numerous (preventable) defects – whether it is caused in the manufacturing of a welded, hollow metal door frame with tolerance issues to fit the wall-frame opening, and/or in supplying to the sites as Walsh (2019) states: "arrives at the site prepped wrong by the manufacturer … and [will] have to be field altered." Such defects are eliminated in a *Qwikinstall* metal door frame as its system is designed for assembly-to-size and accommodated by mounting brackets.

Another defect source is due to handling for installation, during storage, and delivery to points of installation: "[Welded] Hollow metal frames are usually shipped to the job site in an over-the-road common-carrier" which may potentially cause damages to each frame. Once at the site, prior to delivery to points of installation the frames need to be stored in a dry area – whether it is an enclosed, substantially water-tight building structure, or in a sea container. The dry condition is needed considering the compromising effects of weather conditions on the integrity of a WHMDF, especially that the "prime paint (only provided for shipping purposes) does not last for more than a month (Mastroianni, 2019)." In contrast, a *Qwikinstall* metal door frame can conveniently arrive at points of installation when its delivery is justified for the time.

Rework can also be a result of the immediate need for maintenance after completion of work: the immediate dependency of steel-stud wall framing and WHMDF installation leaves a WHMDF vulnerable to potential damages often caused by construction equipment, and skilled trades traffic – and as Mastroianni (2019) stated "most of the time door frames are installed during [wall] framing which often leads to damage in the field – because they are installed so early." Such undesirable re-work is prevented in a *Qwikinstall* metal door frame as it may be installed (up to) immediately before its door and hardware are placed.

- ### Schedule

The *Qwikinstall* metal door frame transfers the physical dependency between a metal door frame and its surrounding wall framing to a convenient – and logically sound – relationship between a metal door frame and its door. As a result, for one thing, removes schedule constraints to advance construction of wall framings prior to delivery of metal door frames: that is, an expected two- to eight-week lead time for delivery of a WHMDF, and understanding that these door frames are "the first items required on a job site when stud walls start". These constraints are made worse "when the Architectural Finish package is released later while the building enclosure floors are being completed (Mastroianni, 2019)."

Conclusion

Applying Lean Thinking principles in the Construction Industry is to minimize, if not to eliminate, waste (rework and waiting for either work or workers). Just-in-Time (or rather Justified-for-Time) planning has long been among efforts to minimize waste.

Welded hollow metal door frames (WHMDF) are often fabricated off-construction sites before arriving for installation on a project site. The sequencing priorities of installing a WHMDF with construction of its surrounding wall is governed, among other factors, by presence of "physical relationships" between these structural components. The choice of when to install the WHMDF relative to the surrounding wall faming (studs only or studs and drywall) is a tradeoff decision between workflow, rework, and schedule. If the install is before, during, or after the surrounding wall framings, something has to be traded-off. It is a situation where it is not possible to have your cake and eat it too.

Qwikinstall removes the necessity of installing a door frame system before or during construction of wall-framings. It also supports a just in time strategy. Two experiments were conducted to evaluate and better understand the impact(s) of *Qwikinstall* metal door frame system from Lean Thinking points of view. Three volunteer construction General Contractors constructed a steel-stud wall framing according to two simple, and different architectural layouts, mounted gypsum (drywall) boards, and installed metal door frames. The focus of the experiment (I) was a welded, hollow metal door frame system; and *Qwikinstall* metal door frame system was the subject of experiment (II).

Illustrated by statistics of Figure 14, total number of activities conducted for placement of a *Qwikinstall* metal door frame system considerably improved in case of construction General Contractors A, and B in comparison with population of activities in experiment 1.

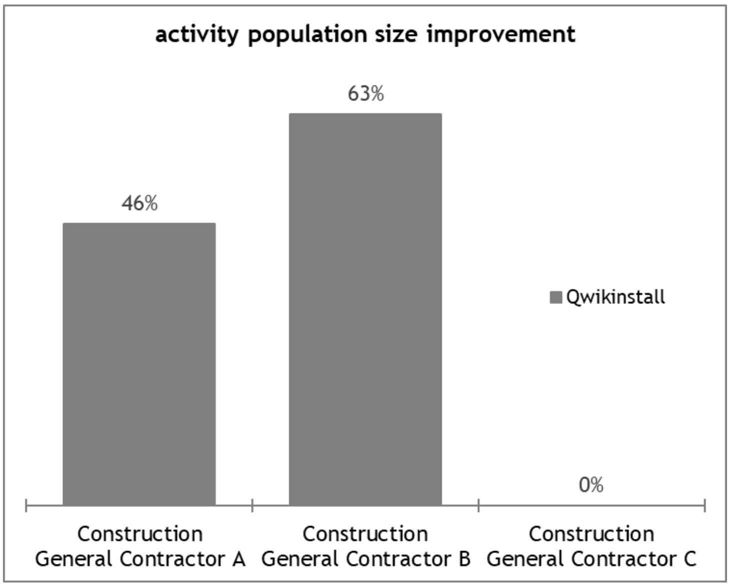


Figure 14. Improvement of Activity Population Size in Experimentation (II)

While the workable design of a *Qwikinstall* metal door frame system accommodated an uninterrupted, easy installation process (i.e., Ease of Installation), its Just-in-Time flexibility – or rather readiness – also contributed in workflow (summarized in Figure 15) improvement, rework, and Schedule performance in these experiments. Such, too, comfortably accommodates the consideration of project-specific work sequences so continuity of work-flow, and its reliability will be maintained – a goal which Work Structuring aims to uphold (Howell & Ballard, 1999; Tsao, Tommelein, Swanlund, & Howell, 2000; Tsao & Tommelein, 2002).

One may argue that there is always the opportunity of selecting a Knock-Down Metal Door Frame (KDMDF) system – not only as an alternative to a welded, hollow metal door frame, but also for its paralleled serviceability with *Qwikinstall*. "Open corners and plastic plugs over fastening screws" of a KDMDF presents an "aesthetically" unpleasant (Mastroianni, 2019) alternative in comparison to superior appearance of a WHMDF. Although costs are higher for welded versus knock-down door frames due to the additional labor involved in the welding and finishing process, welded frames reduce the amount of job-site labor required to assemble and properly install a frame. Additionally, KDMDF raises concerns from stand-point of its stability which in some applications do not satisfy building-code regulations.

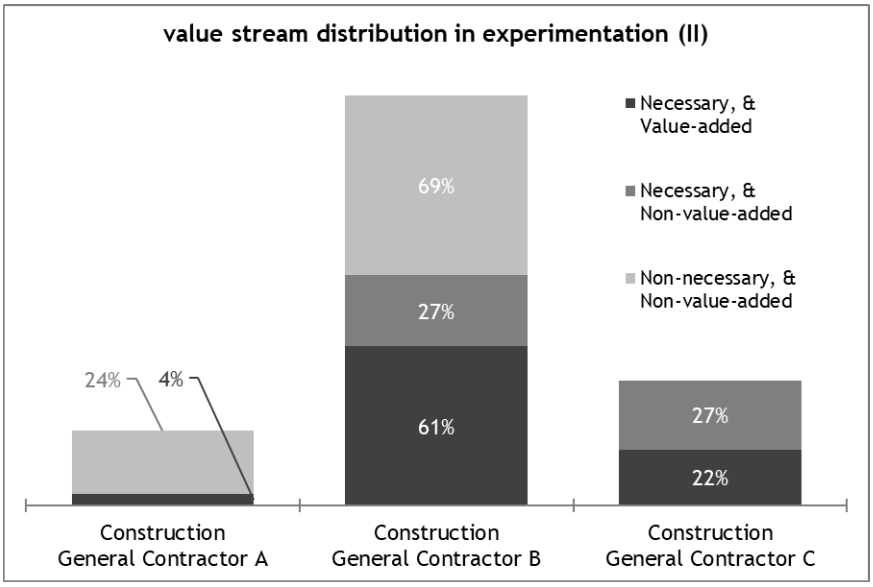


Figure 15. Improvement of Value Stream Activities in Experimentation (II)

A *Qwikinstall* metal door frame system not only provides a workable design of a KDMDF system, but also delivers quality, serves reliably, and is a durable alternative for a welded, hollow metal door frame system. As Mastroianni (2019) stated: "*Qwikinstall* is not much different from the current welded, hollow metal door frame" system – as it is "a split frame … nearly identical in dimensions to a standard [welded] hollow metal door frame that could be installed after drywall [boards]".

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