

Efficacy of Improved Gang-Box Prototypes: A Qualitative Case Study

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Many aspects contribute to construction productivity rates, including jobsite storage and organization. One ubiquitous form of local storage is the "gang box;" typically an open metal container utilized by most construction trades to store materials, tools and equipment on construction jobsites. These boxes provide a secure storage platform which can be left on a construction site, but are historically structured with a single open storage space, which leads to accessibility issues. This paper describes qualitative pilot field testing of two new prototype box configurations developed through an interdisciplinary program between construction management and industrial design students at Auburn University to determine potential efficacy and impact on labor productivity associated with storage, access and organization. The prototypes were field tested on four construction projects across six major construction trades, with qualitative feedback gathered and analyzed from both tradesmen and field management. Findings are compelling that there is potential for improvement to jobsite productivity.

Key Words: Construction, Productivity, Gang Box, Organization, Storage

Introduction

Construction labor productivity is an important and strongly debated subject. While there are numerous factors which can affect the productivity of construction work, one aspect which impacts productivity is the availability of tools and materials on a project site. Material and tool storage can take on many forms on a site, and can vary depending on the nature of a job. On most construction jobsites of reasonable size, gang boxes provide organization and security for tools and materials that are desired to be accessed regularly throughout the workday and can be left on site. They are typically made of 16 gauge steel with welded seams; and although their sizes can vary, most are typically only produced as one of a few different designs. One of the most common types is the "chest" style box. The primary problem with this box lies inherently in its lack of organizational design. It is typically fashioned with a singular primary compartment where all materials and tools, regardless of size or shape, are stored. This allows smaller objects to fall to the bottom of the box under the larger, more bulky items, which often poses significant problems when attempting to locate and retrieve specific items.

Given the significant relationship which gang boxes have with storage and productivity, this paper presents a qualitative case study of two new prototypical storage configurations and their potential efficacy and impact on construction productivity.

Literature Review

Currently, there is little existing literature on construction storage equipment per se. Evidence does show, however, that the time which workers spend finding tools has a large impact on construction labor productivity (Goodrum, et al. 2009). And while there is a lack of literature specifically on jobsite storage, there is much data available on construction productivity as a whole, which is relevant to understanding the gang box's place in construction productivity.

Research shows that the construction industry believes that, in general, productivity is under their control; that uncontrollable external conditions do not ultimately drive productivity, and that the implementation of innovative approaches can improve labor productivity (Rojas & Aramvareeku, 2003). According to Thomas, et al. (2003) there is strong evidence suggesting that utilizing lean construction management principles regarding materials,

information and equipment availability leads to better performance. Rojas & Aramvareekul also add that productivity is of the utmost importance to the construction industry; because "higher productivity levels usually translate into superior profitability."

Material and Tool Management

Thomas et al. (2005) define material management "as the allocation of delivery, storage handling spaces, and resources for the purposes of supporting the labor force and minimizing inefficiencies due to congestion and excess material movement." Sweis et al. (2008) state that 8% of the direct labor cost is related to material management. Although it is somewhat difficult to pinpoint exactly where time can be reduced because of the lack of standards for measuring labor productivity in construction, areas that are direct causes for losses in labor productivity are the unavailability of the appropriate materials, tools, and equipment as well as poor organization on the jobsite (Hewage and Ruwanpura, 2006.) They show that there is significant time spent searching for tools and material and that this time could be reduced with the proper measures and devices implemented into the jobsite. Thomas et al. (2005) report that material management deficiencies that include running out of materials, poor housekeeping, double handling of tools, materials and equipment, and improper storage can reduce labor productivity by 40%.

Oliver III (1990) stated that "improper tools, poorly maintained tools and equipment, and equipment shortages cause the construction worker to expend an inordinate amount of energy." If workers can get to the resources they need to perform their work more efficiently, productivity is expected to increase. Dai et al. (2009) state, "It is important to know what craft workers need and what affects their performance in order to accomplish productivity improvement." The study revealed the craft workers' perceptions on what affects their jobsite productivity. It found that the availability of consumables, hand and power tools, the lack of power sources, the misplacement of tools, and the availability of material were frequency factors that had a significant impact on productivity.

Productivity Lag in Construction

Many researchers concur that the construction industry is lagging in productivity improvements and is stagnant with regards to technological innovation compared to other industries. (Goodrum et al., 2009), (Hewage and Ruwanpura, 2006). Koningsveld and Henk (1997) state that the pace of construction innovation is "most conservative" as compared to other branches of industry, while Chapman et al. (2012) note that the construction industry has recently experienced a perceived reduction in overall productivity.

Thomas et al. (2003) explain that labor is the most flexible construction resource, and if used correctly, the flexibility and flow of labor can be an invaluable asset to accomplishing onsite goals. Working areas and labor needs dramatically change throughout the course of a project. The type of work individual workers are involved in depends greatly on the specific point in the construction schedule along with the duration allotted for that specific activity. If labor is misused and mismanaged, this flexibility will result in very little work being completed with any aspect of efficiency. Poor workforce management caused almost 80% of all inefficient time spent on the project in which Thomas et al. collected data.

Prototype Design

Background

In 2011, two gang box prototypes were designed through a collaborative program in which design, engineering and construction students from Auburn University were partnered with relevant end-users and manufacturers. The purpose of these prototypes was to utilize new and innovative organizational features which could allow users to complete their jobs more easily and productively. Gang box design had not progressed significantly in nearly 50 years, and manufacturers were interested in introducing new designs to improve productivity (Peterson, 2012). After collecting data and distinguishing which features were most important in improving gang box design, a 'modified chest' prototype (figure 1) and a stackable front-access prototype (figure 2) were developed. These as-built boxes were used to collect all research data reported in this paper.

Figure 1: Modified chest prototype

Figure 2: Stackable front access prototype

Modified Chest Prototype

The modified chest box is 39" high (when closed and mounted on casters), by 48" x 30" and utilizes a single hinged lid for access into the top of the container. The most noticeable design feature of the prototype gang box is a large drawer which opens from the front of the unit, allowing easy access to large, bulky items. The drawer utilizes an adjustable and removable divider, allowing the user to customize that storage space. As a result of the drawer, there is a partition which effectively splits the box into upper and lower storage areas. The upper and lower areas of the prototype use independent locking systems, allowing one area to be locked while the other is not. The upper storage area of the prototype utilizes welded dividers to create areas of varying sizes for organization. Additionally, there is a drop-down plan table, which also acts as a plan storage area when not in use, and there are also interior battery powered lights in the top lid, to allow users to see better in dark conditions.

Stackable Upright Front-Access Prototype

The upright, stackable gang box was designed to be fully modular and outfitted to fit an individual work crew's needs for trade specific work. The box is segmented into an upper and lower half, where the sections can be disassembled and reassembled for transportation, maneuverability, and space restrictions. The prototype is outfitted with two vertically hinged doors per section, dividing the box into four quadrants when fully assembled. The doors operate independently of one another allowing access to individual quadrants. The prototype includes four pullout drawers along with a bisecting shelf in the upper section. A small storage and utility cart has been incorporated into the design and fits into the box's lower left quadrant. The cart is designed to be stored in the box when not in use.

Methodology and Results

Research Approach

The nature of testing individual functional prototypes dictated a qualitative approach. Additionally, the number of factors which can affect construction labor productivity, and attempting to control all outside variables which can affect productivity during research, would have been impractical to manage. For this pilot effort, end users' opinions of the prototypes were determined to be the efficacy metric, rather than to try and measure productivity differences based on their use. Care was taken by the authors to develop a pool of respondents that would provide useful and relevant qualitative data. Knowing that the quantity of respondents would not be large enough to provide quantifiable verification of the findings, an effort was made to utilize respondents who would represent many trades across the construction industry; thus allowing for credible data from a diverse survey base.

Process

Independently for each prototype, data was collected in three separate manners, across multiple construction trades on four separate jobsites, over a six week period. Data collection was conducted separately for each prototype, and included: Observation of current gang box use, surveying end users who had not tested the prototypes (but were familiar with them), and surveying end users who had tested the prototype in an actual workplace context. It was specifically determined to not observe workers while they used the prototype chest gang box, to avoid bias and changed work habits associated with the Hawthorne Effect.

The authors first observed the manner in which construction workers currently utilize gang boxes. On multiple jobsites, crews across several trades were shadowed to form a full understanding of current use of gang boxes in the construction industry. The other forms of data collection were performed simultaneously, and consisted of surveying end users who had not tested the prototypes but were familiar with them (figure 4), as well as surveying end users who had conducted field tests of the prototypes. Both those who had tested the prototypes and those who had only observed it were given the same survey.

In total, the prototypes were tested on four separate construction sites over twenty-five work days over four significantly different types of construction sites. Six trades participated in survey efforts with a total of twenty six respondents. Respondents consisted of workers from the electrical, plumbing, carpentry, concrete, drywall, and sheet-metal trades.

The first field tests were conducted at a historic restoration site of a municipal building originally built in1921. The project included asbestos remediation as well as having parts of the building in operation while the renovation took place. The subcontractors relied heavily on the use of gang boxes in the restoration project due to the limited space allotted. The crews were restricted to designated areas where they were required to house their boxes. The prototypes were used over a three day period by a plumbing subcontractor and viewed in depth by the surrounding trades including electricians and sheet metal workers.

The second field tests were conducted at a nine story, vertical high rise hotel in an urban setting. The prototypes were tested for thirteen working days by a concrete and carpentry crew on the top (ninth) floor of the project where they constructed formwork, installed rebar and poured the ninth floor slab along with erecting the formwork for the elevator shaft. The prototype was flown to the top floor by the project's tower crane and was stored uncovered and exposed to weather for the entire duration. (figures 3 and 5.)

Figure 3 – Prototype being flown at site for field use

Figure 4 – Demonstration and interviews on site

Figure 5 – Transportation of prototypes to new study site

The third tests were conducted on an approximately 240,000 square foot recreational facility for a period of five days by a drywall subcontractor. This site was particularly congested with little room to maneuver equipment and lay down materials. Due to this, the drywall subcontractor had difficulty obtaining the resources and authority to deliver the boxes to the working area in the limited amount of time available; therefore, the crew was only able to get supplemental use from the prototypes instead of using them as their primary gang box.

The fourth and final tests were conducted on the site of an eventual 26,000 seat collegiate football stadium. It was a large site with multiple out-buildings in addition to the primary structure of the stadium. The prototypes were used by an electrical subcontractor performing overhead rough-in for a total of four working days. The box was moved via a fork lift on this project.

Surveys

IRB-approved surveys were in the form of written response, anonymously and voluntarily completed by end users at each site. Each survey utilized four Likert scale questions, allowing the respondent to use a 1-5 scale to indicate their opinion of the question statement. A "1" indicated strong opposition to the statement while a "5" indicated strong agreement to the given statement. Additionally, there were three open-response questions, as well as an opportunity for additional comments. The complete results of the "chest box" surveys can be found in Appendix A.

Results

Likert Scale Statement	Average Response
The prototype gang box would be easier to use than a traditional gang box	3.65
The prototype gang box would keep my materials more organized than a traditional gang box	4.42
I can perform my job more easily with the prototype gang box	4.00
If possible, I would rather use the prototype gang box than a traditional gang box	3.92

Table 1: Condensed Survey Results- "Modified Chest" prototype

Overall, the data shows that end users prefer the prototype chest gang box over a traditional gang box. As seen in Table 1, the high average response to each question shows a favorable view of the prototype from construction professionals. Most notably, for the statement, "The prototype gang box would be easier to use than a traditional gang box," 65% of respondents either agreed or strongly agreed. For the statement, "The prototype gang box would keep my materials more organized than a traditional gang box," 85% of the respondents either agreed or strongly agreed. While each question indicated a positive view collectively, some trades had more affirmative reactions than others. Electricians, carpenters, and drywall and concrete workers had consistently high reviews of the prototype, while plumbers and sheet-metal workers found it less favorable (full cross-referenced results in Appendix A.)

For the stackable front-access prototype, the findings show that generally the workers had a positive response to the box with an average score across all trades and statements of 4.33 out of 5. Ninety percent of respondents agreed or strongly agreed to the statement, "The ability to lay out a box according to specific needs would allow you to locate and retrieve items more quickly than is currently possible," while 5% disagreed. The responses to the statement, "Estimate the amount of time spent loading and unloading tools and materials from a cart to a traditional gang box in a day," are varied when compared to the other responses. The answer that was selected most often was 10-20 min/day with 55% of the responses. To the statement, "I am willing to give up storage space in the prototype to house the cart," 40% of respondents agreed or strongly agreed, while 30% disagreed or strongly disagreed. Of these responses, 10% are in strong agreement and 20% in strong disagreement.

100% of respondents agreed or strongly agreed to the statement, "The prototype gang box was easier to use than a normal chest gang box." The statement, "The prototype gang box kept my materials more organized than a normal chest gang box," received an average score of 4.85, with which 85% of the respondents strongly agreed. 92% of respondents agreed or strongly agreed to the statement, "I can perform my job more easily with the prototype gang box," with no disagreements. The statement, "If possible, I would rather use the prototype gang box than a traditional chest box," has an average response of 4.69, and 100% of respondents agreed or strongly agreed.

Authors' Conclusions

Based on the results of this study, end users believe that the prototype chest gang box as well as the stackable drawer/cart based box can allow them to complete their jobs more easily than a traditional chest box. The ability to complete one's job more easily is a direct corollary to worker productivity, so it is reasonable to determine that the prototype boxes could positively affect construction worker productivity.

Based on the data, workers find the organizational properties of the modified chest prototype to be superior to current models. While this could improve productivity through a decrease in idle time to locate materials and tools, additional productivity benefits of the prototype chest gang box can come from the potential positive side effects of

utilizing a user friendly storage platform: more efficient space use, less worker fatigue, and improved overall morale. Responses strongly indicated that the prototype chest gang box would be a viable alternative to traditional chest gang boxes if commercially produced. The features which were included on the as-built prototype which were most favorably received were the large front drawer, the fold-down plan table, and the charging station.

Some trades more so than others found the prototype chest gang box to be more favorable, which was predicted. As this prototype incorporates more features and organizational tools than traditional chest gang boxes, it is reasonable that the same innovations which allow the prototype to better serve some trades will encumber others, depending on how they utilize gang boxes. While the prototype chest gang box might not be marketable to as wide a market as a traditional chest gang box, its superior ability to assist certain trades perform their work would make its production a practical choice for both end users and the manufacturer.

For the stackable upright box, even though most trades preferred the prototype to a traditional open chest box, the electrical and carpentry trades were the most enthusiastic about the new design. These trades often use small materials and tools of differing shapes and sizes during their work. The prototype gang box allowed them to store their materials in an organized fashion allowing for expedited location of the needed materials. For one electrical crew, workers stated that the prototype design increased both productivity and security. They stored their more expendable materials in the upper section while leaving it unlocked, and they locked their expensive tools and materials in the lower section. This allowed any member of the crew to return to the box for inexpensive consumables without having to get the key from the foreman in order to retrieve the needed supplies. The primary design concepts that improved organization and worker ease of use are the eye level design, the easy access to the individually locking quadrants, and the organizational features such as the drawers, shelf, and multiple size storage areas. These organizational features allowed the crews to layout the contents of the box in a specific manner and easily locate and retrieve the contents within.

While the contractors that utilize smaller tools and materials were enthusiastic about the box, contractors that utilize larger, more bulky tools did not show as great of a desire to use the prototype as their primary gang box. It was more difficult for the contractors that stored larger items to utilize the organizational features of the prototype box, and would only be feasible for them to use the prototype as a supplemental box to their current, open boxes. Most of the end-user tradesmen liked the idea of the incorporated cart coming with the box; however, there was concern about the space lost due to the incorporation. The design idea behind the cart was to decrease time loading and unloading the cart each day; instead the worker would simply store and secure the loaded cart in its entirety in the box. Many workers expressed that they would rather have the empty space to store larger tools and materials than store the cart inside the box.

In summary, the authors believe that the two prototype boxes present a compelling argument that innovation in tool and small material storage could have a notable impact on construction productivity. The results from this study suggest that efforts to employ improved products and processes are of interest to many stakeholders.

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Appendix A

Survey Data

Responses		Test Days		Likert Scale	
Total	**26**	**Total**	**25**	1	Strongly Disagree
Plumbing	4	Vance Courth	3	2	Disagree
Electrical	9	BJCC Westin	13	3	Neutral
Carpentry	2	AU Health &	5	4	Agree
Concrete	4	ASU Stadium	4	5	Strongly Agree
Drywall	4				
Sheet-Metal	3				

Question 1

The prototype gang box would be easier to use than a traditional gang box

Trade	1	2	3	4	5	Avg.
Plumbing	1	1	2		3	3.43
Electrical				4	2	4.33
Carpentry				2		4.00
Concrete	1		2	1		2.75
Drywall				3	1	4.25
Sheet-Metal		1	1	1		3.00
Total	2	2	5	11	6	3.65

Question 2

The prototype gang box would keep my materials more organized than a traditional gang box

Trade	1	2	3	4	5	Avg.
Plumbing		1		1	2	4.00
Electrical				2	7	4.78
Carpentry				1	1	4.50
Concrete				2	2	4.50
Drywall					4	5.00
Sheet-Metal			3			3.00
Total		1	3	6	16	4.42

Question 3

I can perform my job more easily with the protoype gang box.

Trade	1	2	3	4	5	Avg.
Plumbing		1	3	1		3.00
Electrical				3	5	4.63
Carpentry				1	1	4.50
Concrete			1	2	1	4.00
Drywall				3	1	4.25
Sheet-Metal		1	1		1	3.33
Total		2	5	10	9	4.00

Question 4

If possible, I would rather use the protoype gang box than a traditional gang box.

Trade	1	2	3	4	5	Avg.
Plumbing		1	1	2		3.25
Electrical			1	1	7	4.67
Carpentry				1	1	4.50
Concrete	1		1	1	1	3.25
Drywall				3	1	4.25
Sheet-Metal		1	2			2.67
Total	1	2	5	8	10	3.92

Voluntary Comments

Trade	Comment
Electrical	The prototype gang box was very nice and helped me do my job
Plumbing	Size needs to be larger; tools are constantly added
	Large drawers should be double slide.

Question 5

Which features do you like about the protoype gang box?

Trade	Response
Plumbing	The sliding bottom drawers work good
	The top
	The storage drawers
	The drawer in the bottom and seperation of paperwork in the lid
Electrical	The receptical for charging drills and drawer for blueprints
	The charge station
	The print table (but it needs to be larger) and battery charger
	The room it provided
	The print table, receptical station, and easy locking
	The power dock, the big drawer, and organization options up top
Sheet-Meta	The trays and drawers
	The top trays
	The bottom half
Drywall	The top and bottom shelves
	The shelves
	The weather-proof outlet and drawers
	Overall durability
Carpentry	The heavy-duty casters
	The print table and sliding drawers
Concrete	The extra shelf space
	The drawers
	The overall size

Question 6

Which features do you *not* like about the prototype gang box?

Trade	Response
Plumbing	It was a little smaller than usual
	The drawers are not built thick enough and slides aren't smooth
Electrical	Bottom drawer tough to open; can't fit 4' level in the box
	The slide-out drawer needs work
	The bottom drawer needs work
	The lock on the bottom drawer needs to be improved
	Not enough square footage
Sheet-Meta	Bottom drawer needs to be doors
	The tray
	Bottom drawer is too tall
Drywall	Need more brackets for support
	The locking device
Carpentry	Not enough storage space
Concrete	The heavy lid
	Color
	Not accessible on site

Question 7

Are there any specific features you would like to see in a gang box?

Trade	Response
Electrical	All wheels could swivel
	More power outlets
	All 4 wheels turn and can lock
	Larger wheels
Plumbing	Lights would be nice
	Better mobility, better drawer, convertible top for prints, hangers for cor
Sheet-Meta	Make bottom have a door; get rid of compartments but leave tray
Drywall	Shelves for screws
Carpentry	Drawers
Concrete	A lighter lid