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# EVALUATING THE AWARENESS OF DESIGNING OUT WASTE IN CONSTRUCTION: A LEAN–GREEN SYNERGY

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## ABSTRACT

The construction industry generates millions of tons of material waste annually throughout a project's life cycle. In Lebanon, one million tons of Construction and Demolition Waste were generated during the years 2009 and 2010. To support organizations in enhancing their environmental efficiency, the Green paradigm has emerged. Such a paradigm can be complemented with the Lean management approach paving the way for a Lean-Green synergy. This synergy is based on the alignment of the two approaches on the need to minimize waste, in its different forms, as well as maximize stakeholder value; the client, and the environment. As such, this paper introduces the concept of the Design out Waste (DoW) approach. This approach aims to improve the sustainability aspect of a project, throughout its lifecycle and starting from the early design phase, supported by Lean tools and principles. Specifically, the aim of this paper is to investigate the current state and examine the level of awareness of implementing DoW principles in the Lebanese construction industry through conducting surveys. The survey results showed a low level of awareness of the DoW approach among practitioners in Lebanon with little attention given to waste minimization when making decisions.

## KEYWORDS

Lean construction, Green construction, sustainability, Lean-Green synergy, waste minimization

## INTRODUCTION

Each year, the construction industry generates millions of tons of material waste across the different stages of a project's life cycle (Wang et al., 2014). Estimates also show that 30% of the materials brought to a typical construction site go to waste (Osmani, 2011). More specifically, the construction industry in Lebanon has generated one million tons of Construction and Demolition Waste (CDW) during the years 2009 and 2010 as per the latest available studies (Tamraz et al., 2012). With the absence of a proper regulatory framework to

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manage solid wastes in Lebanon, including CDW, the waste issue has become more critical to handle (Tamraz et al., 2012).

With the increasing cost overruns, clients are requesting a further reduction of waste in the projects (Akintoye, 1995). This can be due to the high proportion of materials cost that amounts to 50%-60% of the project's cost (Polat & Ballard, 2004) . Therefore, any reduction in material waste can lead to substantial cost savings (Polat & Ballard, 2004). Additionally, research shows that failing to apply waste reduction measures in the design phase of a construction project could result in an estimated 33% of the total waste generated on-site (EPA, 2015).

Given the environmental and economic concerns with the large amounts of CDW waste generated each year (Wang et al., 2014) and the clients' need to reduce waste on their projects (Akintoye, 1995)., it is essential to consider sustainable construction (Polat & Ballard, 2004). The Green paradigm has emerged as an approach to support organizations in enhancing their environmental efficiency (Garza-Reyes, 2015). To support the implementation of Green initiatives in construction projects and to maximize value to the client and the environment, Green approaches can leverage the use of tools and principles developed by the Lean community (Huovila & Koskela, 1998).

Lean has initially emerged as a management approach to designing production systems with the aim of maximizing customer value and minimizing waste in its different forms (Koskela et al., 2007). It is governed by a set of 14 principles adopted from the Toyota Production System (TPS) that cover 4 aspects: 1) "Philosophy" which focuses on long-term thinking as opposed to short-term wins, 2) "Process" which focuses on leveraging lean tools and techniques to eliminate any form of waste in the production process, 3) "People and Partners" that focuses on respecting and challenging the people in the organization as well as other stakeholders, such as suppliers, to understand the organization's philosophy and to help them improve and finally 4) "Problem-solving" which aims to solve problems by identifying the root cause in the pursuit of continuous improvement (Liker, 2004). Additionally, Taichi Ohno identified 7 categories of waste that need to be eliminated from any production process. These include (Polat & Ballard, 2004):

1. Product defects
2. Overproduction
3. Inventory
4. Unnecessary processing
5. Unnecessary movement
6. Unnecessary transportation
7. Workers waiting on work

# LITERATURE REVIEW

Although the foundation of the Lean philosophy is rooted in the manufacturing industry, the construction industry has been witnessing a successful implementation of the Lean management approach (Singh & Kumar, 2020). Specifically, Lean in construction emphasizes the need to reduce different types of waste that are present throughout the different phases of a project's lifecycle (Horman et al., 2004). Among the common tools and techniques used in construction are the 5S, visual management, standardization, big room, and continuous improvement along with many others (Liker, 2004). The successful implementation has been reflected in terms of customer satisfaction, waste reduction, cost reduction, and timely project delivery (Singh & Kumar, 2020).

The success of Lean implementation has also been witnessed in the Lebanese construction industry in particular. To start with, Kallasy and Hamzeh (2021) developed a "Lean Culture

Index" to assess the readiness of construction companies in Lebanon to apply Lean tools and principles. The developed index covered all the aspects of the 4Ps: philosophy, process, people and partners, and problem-solving. The authors also proposed practical recommendations to guide practitioners in Lebanon on Lean implementation. Moreover, Hamzeh et al. (2016) analyzed a large-scale construction project case study regarding its first intensive implementation of Lean tools and the Last Planner System (LPS) in Lebanon. The project team witnessed improvements upon implementation including improved performance visualization, better communication among engineers and the foremen, and better linkage of the main project metrics on time, cost, and quality to the principles of the TPS. In another study, Awada et. Al (2016) evaluated the potential of adopting Lean tools and concepts to reduce safety-related incidents in the Lebanese construction industry. The study showed that practitioners understand the benefits associated with such Lean tools to enhance safety management in construction.

Lean and Green approaches align well with the idea of waste elimination, in its different forms, and with the idea of maximizing stakeholder value; the customer stakeholder and the environment stakeholder. As such, a Lean–Green synergy can be considered where the two approaches complement one another. This synergy has become practically possible in construction given that the Lean construction community has shown the potential of considering the environment as a customer (Huovila & Koskela, 1998).

The aforementioned synergy allows for a smooth implementation of Lean tools and principles to achieve - on top of customer satisfaction - environmental benefits in the construction industry. For example, Vieira and Cachadinha (2011) showed that the use of the 5S Lean tool helped maintain a clean and organized site by placing waste containers in the immediate vicinity of the generated material waste as well as sending material waste to their identified locations. The case study presented by Valente et al. (2013) utilized the Gemba Lean practice on a monthly basis to monitor and document the requirements needed to apply for LEED certification. Moreover, just-in-time (JIT) material delivery and Kanban systems were utilized to improve the flow of material on-site (Rosenbaum et al., 2012). In another study, Abou Dargham et al. (Abou Dargham et al., 2019) showed that adopting a pull material delivery system ensured a more efficient use of the material delivery trucks.

Although the integration of Lean and Green approaches has been successful, previous studies mostly address the construction phase of the project as opposed to the different stages of the lifecycle. To spread awareness of the benefits of Lean to improve projects' sustainability aspect during their lifecycle, the Designing out Waste (DoW) paradigm is introduced.

The guidelines of DoW were developed in the year 2000 by the Waste and Resource Action Programme (WRAP) to promote sustainable waste management (WRAP, n.d.-a). It is a methodology implemented from the design phase to control, monitor, and eliminate waste in construction projects. It consists of identifying key waste reduction opportunities, investigating the promising ones further, and implementing the most practical option (WRAP, n.d.-b). The DoW process has presented five key principles described below (WRAP, n.d.-b):

1. *Design for waste efficient procurement:* requires an agreement between the suppliers and project teams to provide only the needed quantity of material at the right time as opposed to batch delivery. The aim is to avoid the storage of excess material on site. Accordingly, this will also reduce potential material damage and thus the need to order new batches (WRAP, n.d.-b). The Lean concepts of the JIT delivery system and the pull approach can be utilized to support a waste-efficient procurement (Abou Dargham et al., 2019) thus reducing excess inventory and potential defects (Polat & Ballard, 2004). As such, this principle aligns well with the following Lean principles of the TPS: "Use pull systems to avoid overproduction" and "Respect your extended network of partners and suppliers by challenging them and helping them improve" (Liker, 2004).

2. *Design for off-site construction:* is based on fabricating construction elements in a controlled factory environment and then shipping them to the site for assembly (WRAP, n.d.-b). It is a method well accepted by the Lean community to efficiently reduce construction waste (Polat & Ballard, 2006). Being in a factory setting, off-site construction entails a production line approach similar to that adopted in the manufacturing industry. In this case, the tasks performed at each workstation are standardized to a certain extent. This must be accompanied by levelling the workload among the different stations to reduce waste in the process. Waste here covers a variety of aspects including inventory, work waiting on workers, and workers waiting on work. Moreover, value stream mapping acts as an effective Lean tool to help identify different types of waste in the production process and thus propose opportunities for improvement (kaizen) (El Sakka et al., 2016). So, this principle aligns with the following principles from TPS: "Standardized tasks are the foundation for continuous improvement and employee empowerment" and "Level out the workload" (Liker, 2004).
3. *Design for materials optimization:* tackles design approaches that consider efficient use of resources without affecting the quality or the design (WRAP, n.d.-b). This can be achieved by minimizing the amount of materials incorporated in the design through value engineering to reduce waste production in the construction phase (WRAP, nd). It can also be achieved by standardizing the materials and components used as much as possible (WRAP, n.d.-b). This principle aligns with Lean thinking by eliminating Muda; waste in its different forms, and using only what is required of the resources (Polat & Ballard, 2004). Additionally, standardizing the materials and components used allows for a smoother standardization of the construction processes which is a core Lean concept as well (Liker, 2004). As such, this principle aligns well with the following principles from the TPS: "Standardized tasks are the foundation for continuous improvement and employee empowerment" (Liker, 2004).
4. *Design for reuse and recovery:* considers the entire life of the materials used on site. Material reuse allows the reduction of the consumption of new raw resources by exploiting materials and the facilities present originally on-site to their fullest capacity before considering new resources (WRAP, n.d.-b). From a Lean perspective, designing projects in a way that allows material reuse requires pulling information from the client in the early design stages (Elmaraghy et al., 2018). Additionally, implementing this principle supports the elimination of Muda by reusing existing materials as opposed to transforming them to waste and using new materials (Polat & Ballard, 2004). In order to effectively design for material reuse and recovery, the project stakeholders need to focus on longer-term goals as opposed to short-term gains. In other words, it might require more effort and some additional costs to reuse and recover existing materials as opposed to ordering new materials. However, in the long run, this will reduce the overall waste generated and will add value to the customer and the environment. So, the principle is rooted in the following Lean principle of the TPS: "Base your management decisions on a long-term philosophy" (Liker, 2004).
5. *Design for deconstruction and flexibility:* considers the recovery and the deconstruction stages of materials by incorporating methods that facilitate their maintenance and reprocessing (WRAP, n.d.-b). Lean principles can be applied to plan for deconstruction by pulling information from the clients to meet their needs and expectations thus increasing client value (Elmaraghy et al., 2018). Developing a deconstruction plan requires the project stakeholders, including the client, to think about the long term as opposed to focusing on short-term gains. Although this requires additional planning, effort, and potential cost at the early stages of the project design, however, on the long term this is expected to reduce the total waste generated and will add value to the customer and the environment. As such, this principle is rooted in the following Lean principle of the TPS: "Base your management decisions on a long-term philosophy" (Liker, 2004).

Implementing each principle requires effective coordination between the teams of the project: clients, designers, contractors, and subcontractors, from the preliminary design phase (WRAP, n.d.-b). Therefore, following an integrated approach to enhance effective communication starting from the design phase could help avoid several construction problems (Emmitt et al., 2004). From a Lean perspective, following such an approach can practically be achieved by adopting an Integrated Project Delivery (IPD) method (Ballard et al., 2011).

The literature shows the benefits of the DoW approach accompanied by integrated practices in minimizing the waste generated during a construction project's lifecycle which then saves on cost and time and increases stakeholders' value (the client and the environment). Additionally, the urging needs to handle the CDW in Lebanon calls for leveraging the described Lean-Green synergy whereby Lean tools and principles smoothly support the implementation of Green initiatives. As such, this paper aims to study the current state and examine the level of awareness of implementing DoW through integrated practices in the Lebanese construction industry. The specific research questions that this study aims to answer are as follows: 1) What is the level of awareness of the construction industry in Beirut, Lebanon regarding each of the DoW principles? 2) What is the level of integration between the client, designer, and contractor in the early stages of the construction project? and 3) What is the relative importance of time, cost, and waste aspects in construction projects? The study outcomes will act as a baseline for construction practitioners and researchers to identify opportunities for improvement related to implementing Green initiatives backed up by Lean thinking.

# METHODOLOGY

To examine the current practices and the level of awareness of implementing DoW methods through an integrated approach in the construction industry in the city of Beirut in Lebanon, a qualitative approach using questionnaire surveys was followed in this study. Survey-based research can help researchers collect information from a certain group of individuals based on the responses they provide to a pre-defined set of questions (Ponto, 2015). Generally, the researchers start by formulating a set of questions that can help them understand certain preferences or behaviours of the population (Ponto, 2015). Specifically, the Likert scale can be used to measure the attitudes of the individual to identify the degree to which they agree or disagree with a certain statement (Likert, 1932). As it is not possible to collect data from an entire population, a sample of the population is often selected to estimate how the responses of the population (Ponto, 2015). As such, researchers would try as much as possible to select a sample of individuals that have characteristics similar to the population (Ponto, 2015).

The developed questionnaire was based on key findings from the literature regarding the five principles of DoW and integrated practices in construction as well as the synergy with Lean practices. It was divided into two main sections: section one tackled the DoW principles, while section two focused on the integrated approach.

In the first section of the survey, when addressing the first principle, design for waste-efficient procurement, the survey tackled the concept of JIT ordering, supplier cooperation in delivering the needed quantities, the extent of buffers allowed when ordering materials, and the flexibility in the choice of material. The second principle, design for off-site construction, was approached by investigating the reason behind using off-site construction methods and whether the contractor was involved in making such a decision in the design phase. The third principle, design for materials optimization, tested if the designer involves the contractor in the design phase to find solutions for constructability issues and whether the contractor raises such concerns to the designer during construction. In addition, this principle addressed the purpose behind minimizing material cut-offs. The fourth principle, design for reuse and recovery, was studied by examining the use of recyclable and reusable materials in construction projects. The fifth principle, design for deconstruction and flexibility, was addressed by checking if the design accounts for potential future changes and for developing a deconstruction plan.

The second section of the survey targeted the implementation of DoW from the design phase through an integrated approach. The questions addressed the extent to which regular follow-up meetings take place between designers, clients, and contractors and the contractor's involvement in the design phase regarding the construction methods and constructability issues.

Two formats of the survey questions were produced; one for the designers and one for the contractors. Both surveys had the same content. However, the formulation of the questions was slightly modified so that each respondent could better relate to it given their background. The surveys were filled by professionals in the construction field through interactive interviews ensuring the reliability of the collected data.

To measure the different degrees of attitudes and opinions of the respondents, the five-point Likert scale was used (Likert, 1932). An answer of "1" stands for "strongly disagree", an answer of "3" indicates a "neutral" opinion, whereas an answer of "5" means "strongly agree". The awareness level was then measured from the mean score (MS) of each topic under study. In other words, an MS of less than 3 indicates a low level of awareness, whereas an MS of more than 3 indicates a high level of awareness. Questions were formulated in both positive and negative senses to ensure unbiased feedback thus increasing the trustworthiness of the results. Throughout all the survey questions, the relative importance of time, cost, and waste in the project delivery process was measured.

A total of 33 valid surveys were completed upon interviewing professionals in the Lebanese construction industry, specifically in the city of Beirut. The sample of respondents included architects, engineers from different disciplines, contractors, and consultants with an experience range of one to thirty years in the Lebanese construction industry. Specifically, 20 of the surveys were completed by professionals on the designers' teams with experience ranging between 1 and 30 years and an average of 10 years of experience. As for the remaining 13 surveys, they were completed by professionals on the contractors' teams with experience ranging also between 1 and 30 years with an average of 9 years of experience. The responses were collected from a total of 7 organizations; 4 engineering companies and 3 contracting companies.

The collected data were sorted and analyzed using descriptive statistics and a one-sample T-test. Then, recommendations for implementing DoW in Lebanon, with the support of Lean tools and principles, are suggested.

# RESULTS AND ANALYSIS

Table 1 shows the level of awareness of the survey respondents along with the mean and standard deviation on the following items: each of the DoW principles, the integrated approach, and the overall DoW approach. Moreover, Figure 1 shows the corresponding box plots. The results obtained are then analyzed to understand the current construction practices.

Table 1: Level of awareness summary

| Section | < 3 | = 3 | > 3 | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Principle 1 | 51.92% | 21.15% | 26.92% | 2.8 | 0.7 |
| Principle 2 | 53.54% | 19.19% | 27.27% | 2.6 | 0.6 |
| Principle 3 | 55.70% | 17.72% | 26.58% | 2.8 | 0.5 |
| Principle 4 | 68.18% | 21.21% | 10.61% | 2.2 | 0.3 |
| Principle 5 | 57.50% | 15.00% | 27.50% | 2.7 | 0.65 |
| Integrated approach | 58.18% | 19.39% | 22.42% | 2.6 | 0.7 |
| DoW | 57.50% | 18.95% | 23.55% | 2.5 | 0.6 |

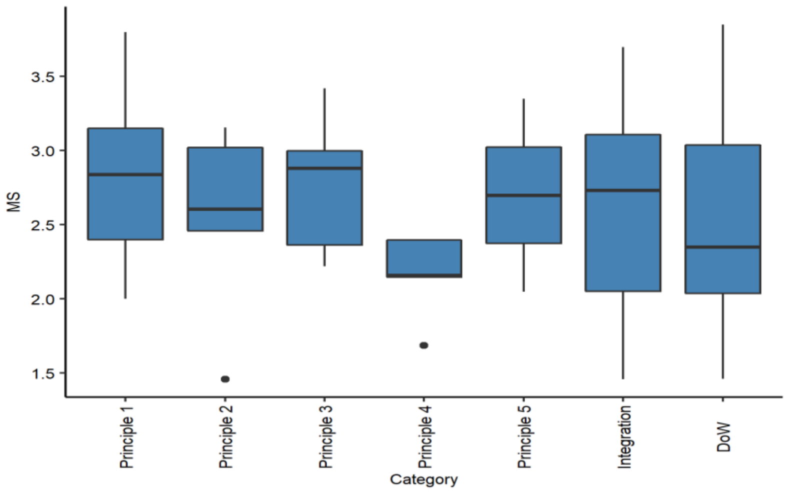


Figure 1: Level of awareness box plots

## PRINCIPLE 1: DESIGN FOR WASTE-EFFICIENT PROCUREMENT

Table 1 shows the relative frequency of the respondents who answered less than 3 (52%), 3 (21%), and greater than 3 (27%) on the questions related to the 1st principle. The box plot in Figure 1 confirms the results by having more than half of the data scoring below 3. The MS of the data turned out to be 2.8 with a standard deviation of 0.7 reflecting a low level of awareness on this principle.

Most of the interviewed contractors order materials in batches and store them on-site as opposed to adopting JIT procurement methods. Their point of view was that ordering in batches helps them save on transportation costs and get better deals from suppliers. Moreover, based on the professionals' answers, the suppliers showed little cooperation in delivering materials in small quantities when needed because it would cost them more. In addition, excess material buffers were often used to account for variability that takes place on-site including material damage, loss, or delayed delivery. Moreover, little flexibility was shown in changing the materials being used to ones that generate less waste.

## PRINCIPLE 2: DESIGN FOR OFF-SITE CONSTRUCTION

Table 1 shows the relative frequency of the respondents who answered less than 3 (54 %), 3 (19%), and greater than 3 (27%) on the questions related to the 2nd principle. The MS of the data turned out to be 2.6 with a standard deviation of 0.6. The box plot in Figure 1 shows that the median is below 3, which means more than half of the scores are below 3. This can be explained by the current practices that follow traditional contractual relations prohibiting the early engagement of the contractor. Hence, the results indicate a low awareness regarding designing for off-site construction.

The results confirm that off-site construction methods were used for the sake of reducing the construction time and getting better quality instead of the purpose of reducing waste in its different forms. In addition, the decision to use such methods was mostly taken in the early design phase without the involvement of the builders, thus increasing the chances of conflicts during construction. As such, current practices have not prioritized maximizing value to both the client and the environmental stakeholders.

### PRINCIPLE 3: DESIGN FOR MATERIALS OPTIMIZATION

Table 1 shows the relative frequency of the respondents who answered less than 3 (56%), 3 (18%), and greater than 3 (26%) on the questions that tested the 3rd principle. The box plot in Figure 1 shows that the median is slightly below 3, which means more than half of the scores are below 3. The MS of the data turned out to be 2.8 with a standard deviation of 0.5, reflecting a low level of awareness regarding designing for material optimization.

The results indicate that most of the targeted practitioners do not consider standardizing the design to reduce the material cut-off generated during construction. In addition, contractors seemed to be hesitant about raising related constructability issues with the designers since they believe that they are two independent entities. On the other hand, designers do not consider addressing contractors about the feasibility of constructing the generated design for the same purpose.

### PRINCIPLE 4: DESIGN FOR REUSE AND RECOVERY

Table 1 shows the relative frequency of the respondents who answered less than 3 (68 %), 3 (21%), and greater than 3 (11%) on the questions related to the 4th principle. The MS of the data turned out to be 2.2 with a standard deviation of 0.3. Similarly, the box plot in Figure 1 shows that the median is below 3 which also confirms that more than half of the data is below 3. Hence, this indicates a low awareness regarding designing for reuse and recovery.

It can be inferred from the results that most of the respondents do not incorporate materials that have a percentage of recyclable content throughout the projects. The clients' perspective on this matter was sought based on the information shared by the respondents. Clients are not aware that they could save on the cost of dumping the materials in landfills by recycling them, which could increase their profit. Additionally, clients might not have a thorough background on the associated environmental value of material reuse and recovery. In addition, choosing materials that can be reused later for a purpose it is suited for, whether on the same project or a new one, is not taken into consideration either. In this case, the old material will be considered unnecessary waste (Muda). Moreover, the project stakeholders might not find it financially feasible to recover and re-use existing material as this would require a certain up-front cost regardless of the long-term benefits. Stakeholders also find it challenging to re-use and recover material between different projects as each project is likely to be handled by a different team. As such, more planning is required between the teams to support a smooth transition of material reuse and recovery.

### PRINCIPLE 5: DESIGN FOR DECONSTRUCTION AND FLEXIBILITY

Table 1 shows the relative frequency of the respondents who answered less than 3 (55 %), 3 (16%), and greater than 3 (29%) on the questions related to the 5th principle. The box plot in Figure 1 shows that the median is below 3 which also confirms that more than half of the data is below 3. The MS of the data turned out to be 2.7 with a standard deviation of 0.65. This indicates a low awareness of designing for deconstruction and flexibility.

The results reveal that most designers do not account for potential future changes in the project during design. Also, most of the contractors do not consider developing a deconstruction plan in the design phase to deal with the CDW generated. This can be explained by their lack of awareness about the cost savings, environmental benefits, and added client value upon reusing and recycling materials as stated in the previous principle.

### INTEGRATED APPROACH

Table 1 shows the relative frequency of the respondents who answered less than 3 (56%), 3 (19%), and greater than 3 (22%) on the questions related to following an integrated approach. The box plot in Figure 1 shows that the median is below 3 which also confirms that more than half of the data is below 3. The MS of the data turned out to be 2.7 with a standard deviation of 0.7.

It could be concluded that there is minimal integration between the client, designer, and contractor altogether in the early design phase to develop strategies to design out waste. Results show that meetings do take place between clients and designers or between clients and contractors. However, these meetings are held further into the project construction phase as opposed to the early stages of design. These meetings often address general updates on the progress of the project, issues faced -if any -, time delays, and cost overruns.

### LEVEL OF AWARENESS OF DESIGN OUT WASTE

Table 1 shows the relative frequency of the respondents who answered less than 3 (59%), 3 (18%), and greater than 3 (23%) on the questions related to DoW: the five principles and the integrated approach. The box plot in Figure 1 shows that the median is below 3, which means more than half of the scores are below 3. The MS of the data turned out to be 2.5 with a standard deviation of 0.6. Hence, this indicates a low awareness of DoW through integrated approaches in the construction industry in Beirut, Lebanon.

The normality of the collected data was confirmed using the Shapiro test with a confidence level of 95%. The PDF of the data is plotted in Figure 2 showing a symmetric distribution. The graph shows that there is a probability of 78.9% of having a low level of awareness (less than 3).

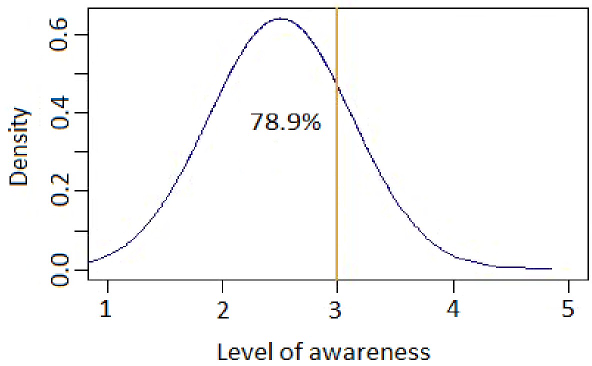


Figure 2: PDF of Level of Awareness of DoW

It was possible to conduct a one-sample T-test since the data was normal to check whether the MS of the survey questions addressing DoW through integrated practices (2.5) is statistically significant from the neutral MS (3). The null hypothesis states that the data is not statistically different from 3 and the alternative hypothesis states that the data is statistically different from 3. The resulting p-value was equal to 0.0002343 which is less than 0.05. Thus, the null hypothesis can be rejected meaning that the data is statistically significant with a 95% confidence level.

### IMPORTANCE LEVEL OF DIFFERENT FACTORS

The survey questionnaire included certain questions that reflect how important the factors of time, cost, and waste are important to the respondent. The results revealed that the most important factors that practitioners take into consideration when delivering a construction project are time followed by cost as Figure 3 shows. The time factor had an MS of 4.1 while the cost factor with an MS equivalent to 3.8. However, the importance of considering waste showed an MS lower than both of the latter (2.5). This shows that professionals focus on time and cost while making decisions. However, they are not aware that the waste factor indirectly affects the other two; investing more in adopting methods that generate less waste will save time and cost in the long run. Additionally, it would increase value to both the client and the environment which is the ultimate goal of the DoW approaches.

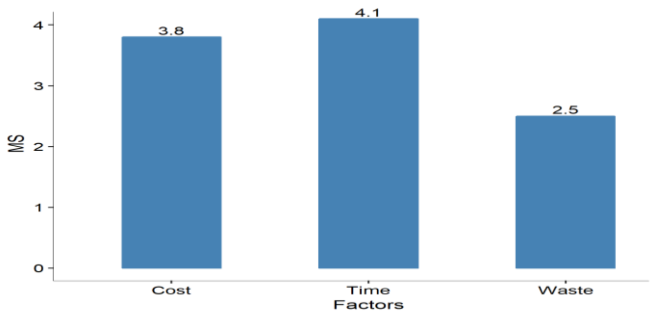


Figure 3: Results for the importance level of the different factors in project delivery

## CONCLUSIONS AND RECOMMENDATIONS

DoW is a strategy that aims at minimizing waste by following five main principles: design for waste-efficient procurement, design for off-site construction, design for materials optimization, design for reuse and recovery, and design for deconstruction and flexibility. It requires the integration between the project stakeholders from the beginning of the project. Lean tools and principles, on the other hand, help support the implementation of the DoW principles in construction projects. As such, the Lean–Green synergy in construction was introduced in this paper. This study also showed how the DoW principles and Lean TPS principles go hand-in-hand with a focus on the 4Ps model: philosophy, process, people and partners, and problem-solving.  A questionnaire conducted among professionals in the construction industry in Beirut, Lebanon, given the high numbers related to CDW waste in the country, revealed a low level of awareness regarding DoW. Also, results showed that professionals' focus in project delivery is the direct time and cost savings disregarding the benefits of minimizing waste to ultimately add value to the client and the environment.

Given the study outcomes, the Lebanese construction industry can benefit from a set of recommendations to support the implementation of DoW accompanied by the corresponding Lean tools and principles. To start with, construction companies need to thrive to build a Lean culture in the organization which would act as the foundation for continuous improvement in the different aspects. Second, construction companies should invest in training employees on the benefits of implementing the different Lean tools and principles to reduce waste and maximize value. Third, the companies should carry on training on the benefits of leveraging these Lean tools in implementing DoW principles to further maximize value to the environment. Fourth, companies also need to guide owners on how they can better define their value while maximizing value to the environment. Finally, it is recommended to implement the DoW along with the necessary Lean tools and TPS principles on a pilot project in an attempt to showcase the potential benefits of minimizing waste, and maximizing the client and environmental value.

Future research should further examine the level of awareness of clients regarding DoW approaches supported by Lean tools and techniques to obtain an overall awareness. Another direction for future research is to investigate, based on a case study analysis, the benefits of implementing DoW principles supported with Lean tools and principles. Finally, the authors will be working on expanding the study by increasing the sample size of the respondents to get a better representation of the current state in Beirut, Lebanon. Additionally, a larger geographical context in Lebanon will be considered. This would help ensure a better representation of the population in the Lebanese construction industry.

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