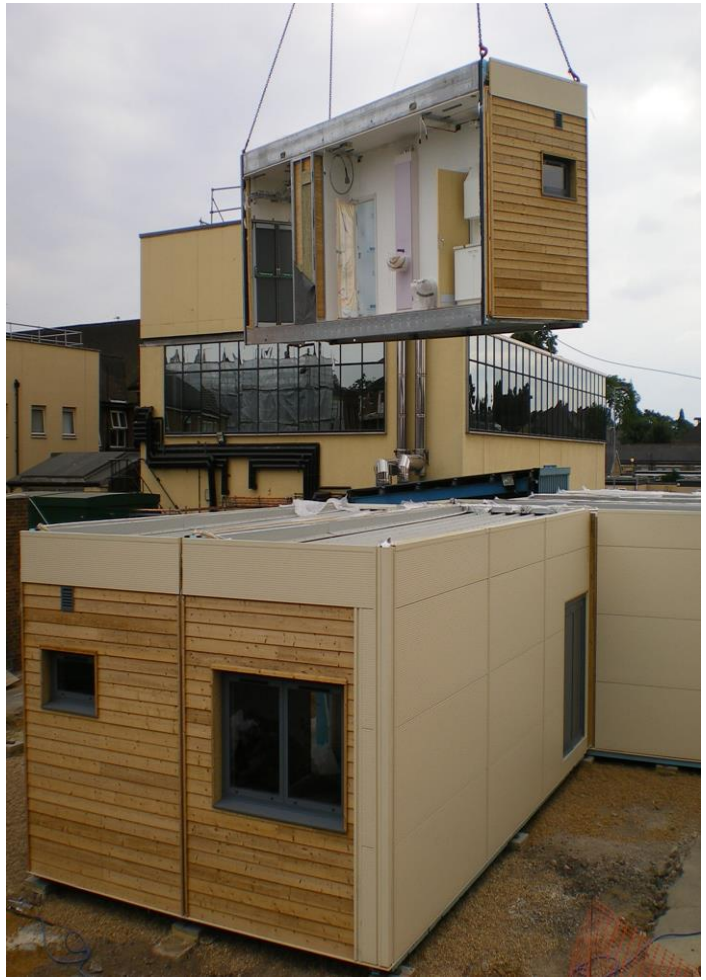
AN AHP APPROACH FOR SELECTING AND IDENTIFYING OFF-SITE CONSTRUCTION SYSTEMS



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INTRODUCTION

- **Traditional** methods of construction have been popular since the end of the **19th century**.

- However, these methods have been witnessing a **high level of waste, low productivity rates, high costs, poor safety records, poor quality control, and long project durations**

(Deffense et al., 2011; Mydin et al., 2014; Kamali et al., 2016)

INTRODUCTION (cont'd)

- As a result, **off-site construction** emerged as an **alternative modern method** aimed at **enhancing the overall traditional process**
- **Off-site construction** is one of the construction strategies that **couples construction with manufacturing**
- Engineers have increasingly turned to using the off-site method due to its ability to **reap the benefits of automotive manufacturing principles** and **achieve the lean construction goals** of adding value while reducing process and material waste

(Howell,1999; Antillón et al., 2014; Vernikos et al., 2013; Howell,1999; Bekdik et al., 2016; Polat et al., 2005)

LITERATURE REVIEW

Off-site construction categories

	Systems	Examples
Off-Site Construction	Sub-Assembly Systems	Windows
	Non-Volumetric Systems	Timber Panels
	Volumetric Systems	Bath Rooms
	Modular Systems	Hotel Rooms

(Gibb, 1999; Goodier and Gibb, 2007; Kamali et al., 2016; Li et al., 2014; Švajlenka et al., 2017)

LITERATURE REVIEW (cont'd)

Off-site construction systems in Lebanon and Syria

	Systems
Off-Site Construction	Non-Volumetric Panelized Systems
	Non-Volumetric Natural Materials Systems
	Volumetric Systems
	Hybrid Systems (Panelized-Volumetric Systems)

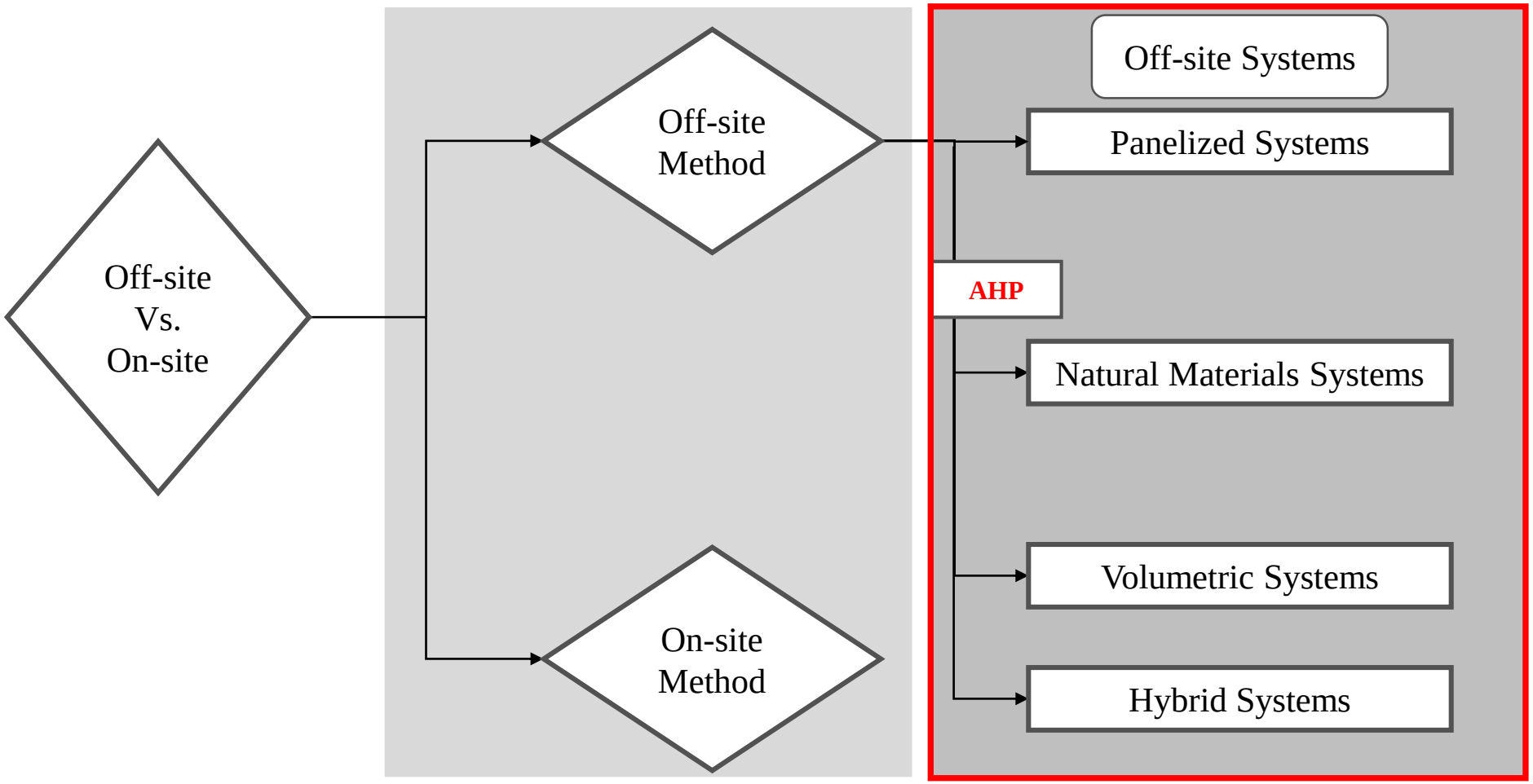
RESEARCH GAPS AND CONTRIBUTIONS

1	None of the previous works have **selected** the optimal off-site construction systems for a given project **while considering value maximization and waste minimization**
2	Carrying out a detailed **study to select the best off-site system has been missing** from the literature review

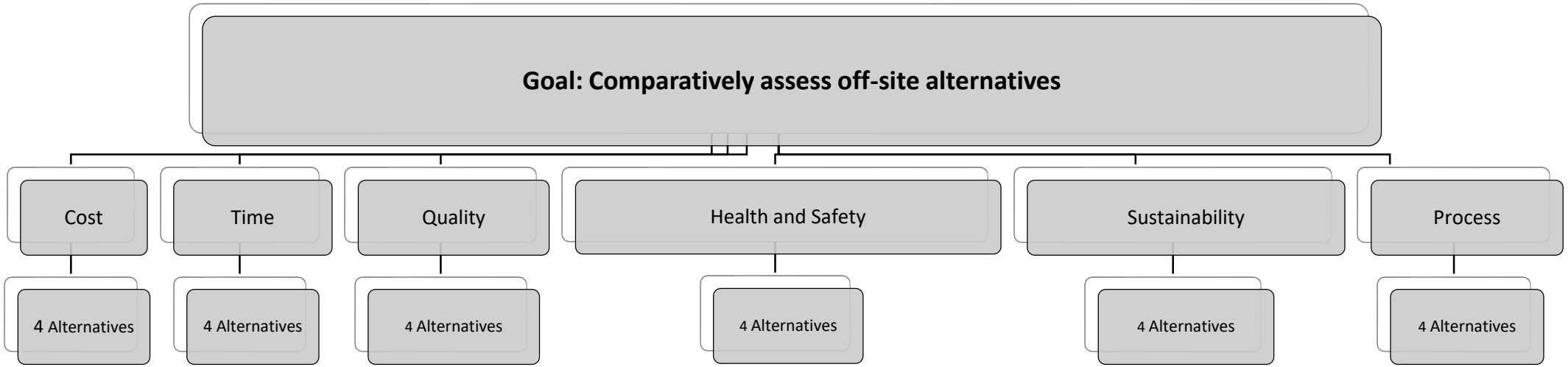
RESEARCH OBJECTIVE

Design **a new decision support tool** targeted at **identifying and selecting** the best **off-site system** for a project at hand while **maximizing the value** and **meeting customer requirements** through **continuous improvement** and **waste elimination**

RESEARCH METHODOLOGY



PROPOSED DECISION MODEL



First Stage

Second Stage

Third Stage

PROPOSED DECISION MODEL (cont'd)

- At the heart of this model lie various off-site building categories for which weights are to be allocated with respect to various decision criteria using the **Analytic Hierarchy Process (AHP) method**.

- AHP, developed in 1980 by Thomas Saaty, is an advanced, powerful, and flexible tool that provides the ability to calculate the degree of importance for each alternative following pairwise evaluations of the criteria introduced by decision makers.

- Most researchers recommend the AHP method as a suitable prioritization technique due to its flexibility and simplicity. Moreover, decision makers can easily fill out the survey without having previous knowledge on AHP.

(Pan et al., 2012b; Saaty, 1980)

AHP SURVEY DESIGN

The survey is divided into three sections:

1. A cover/invitation letter
2. A brief summary of the research topic including the goal of the survey, and chosen criteria and alternatives
3. Questions about the type of systems, the scale system as introduced by Saaty (1980), and the actual pairwise comparison with respect to the cost, time, quality, health and safety, sustainability and process criteria

The AHP pairwise comparison scale

Intensity of weight	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objectives
3	Weak/moderate importance of one over another	Experience and judgment slightly favored one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation

(Saaty, 1980)

AHP SURVEY PARTICIPANTS

- The survey was conducted with a selection of senior construction managers from top off-site builders in the Middle East.
- A total of 20 managers working in 20 different Lebanese and Syrian off-site construction companies responded out of 35 surveys sent
- Most of them have more than 5 years of experience in this field. The data gathered from the construction managers was basically pairwise comparisons for multiple criteria.

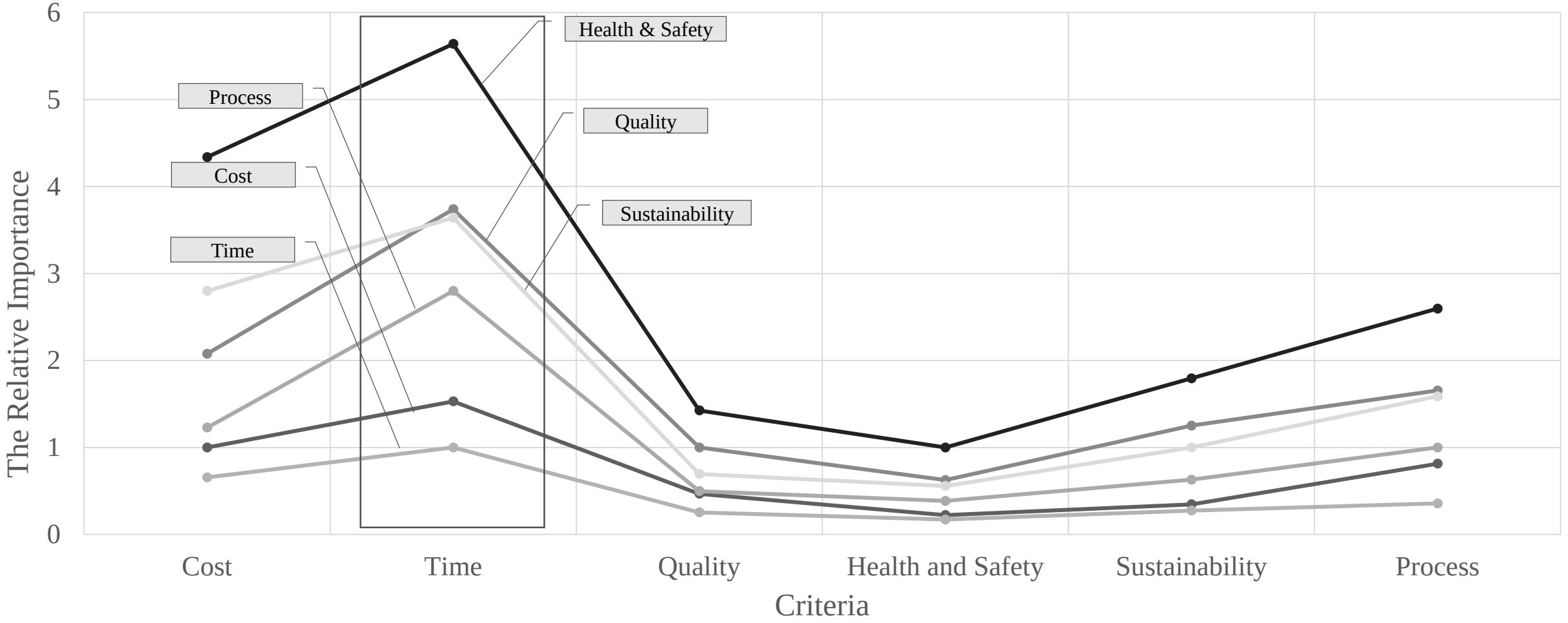
(Saaty, 1980)

ANALYSIS AND DISCUSSION OF RESULTS

The pairwise comparison of one criterion with respect to other criteria

Criteria	Cost	Time	Quality	Health and Safety	Sustainability	Process
Cost	1	1.53	0.47	0.22	0.35	0.81
Time	0.66	1	0.25	0.17	0.28	0.36
Quality	2.08	3.74	1	0.63	1.25	1.65
Health and Safety	4.34	5.64	1.43	1	1.80	2.60
Sustainability	2.80	3.64	0.70	0.56	1	1.59
Process	1.23	2.80	0.50	0.39	0.63	1

ANALYSIS AND DISCUSSION OF RESULTS (cont'd)



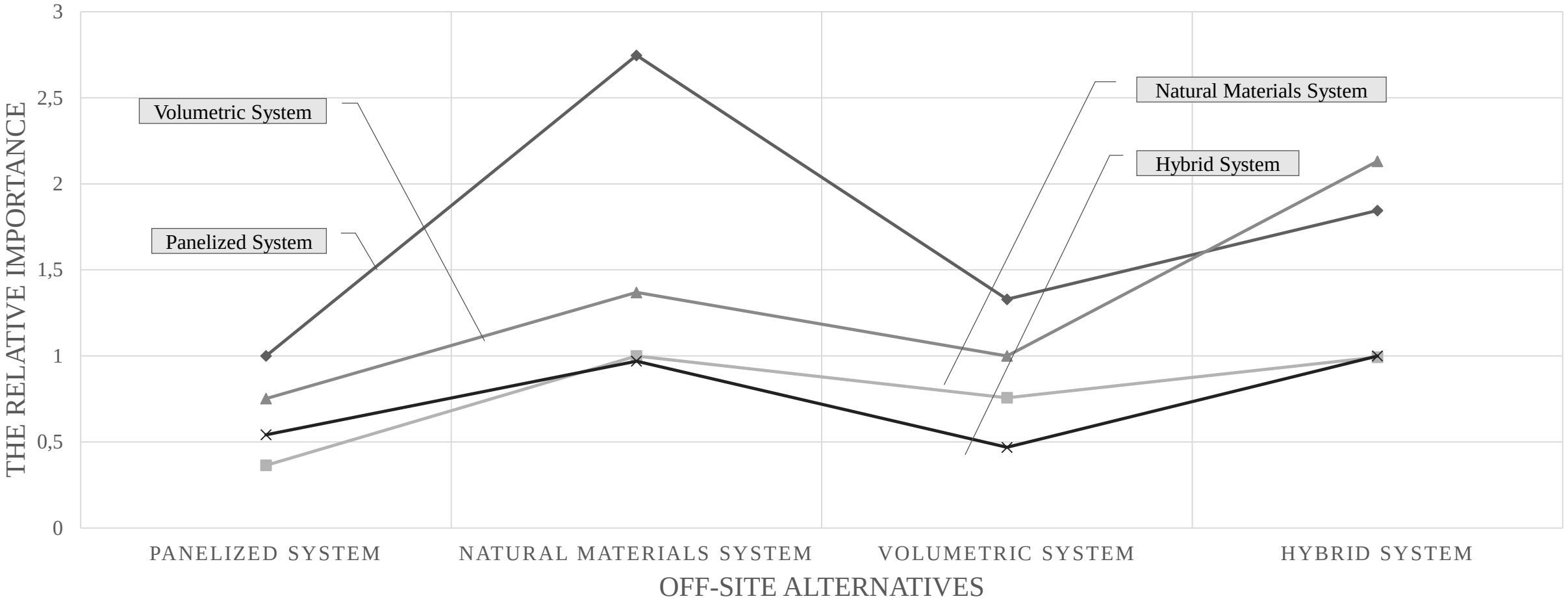
The pairwise comparison of one criterion with respect to other criteria

ANALYSIS AND DISCUSSION OF RESULTS (cont'd)

The pairwise comparison matrix with respect to the cost criterion

Alternatives	Panelized System	Natural System	Volumetric System	Hybrid System
Panelized System	1	2.75	1.33	1.85
Natural System	0.36	1	0.76	0.99
Volumetric System	0.75	1.37	1	2.13
Hybrid System	0.54	0.97	0.47	1

ANALYSIS AND DISCUSSION OF RESULTS (cont'd)



The pairwise comparison results with respect to the cost criterion

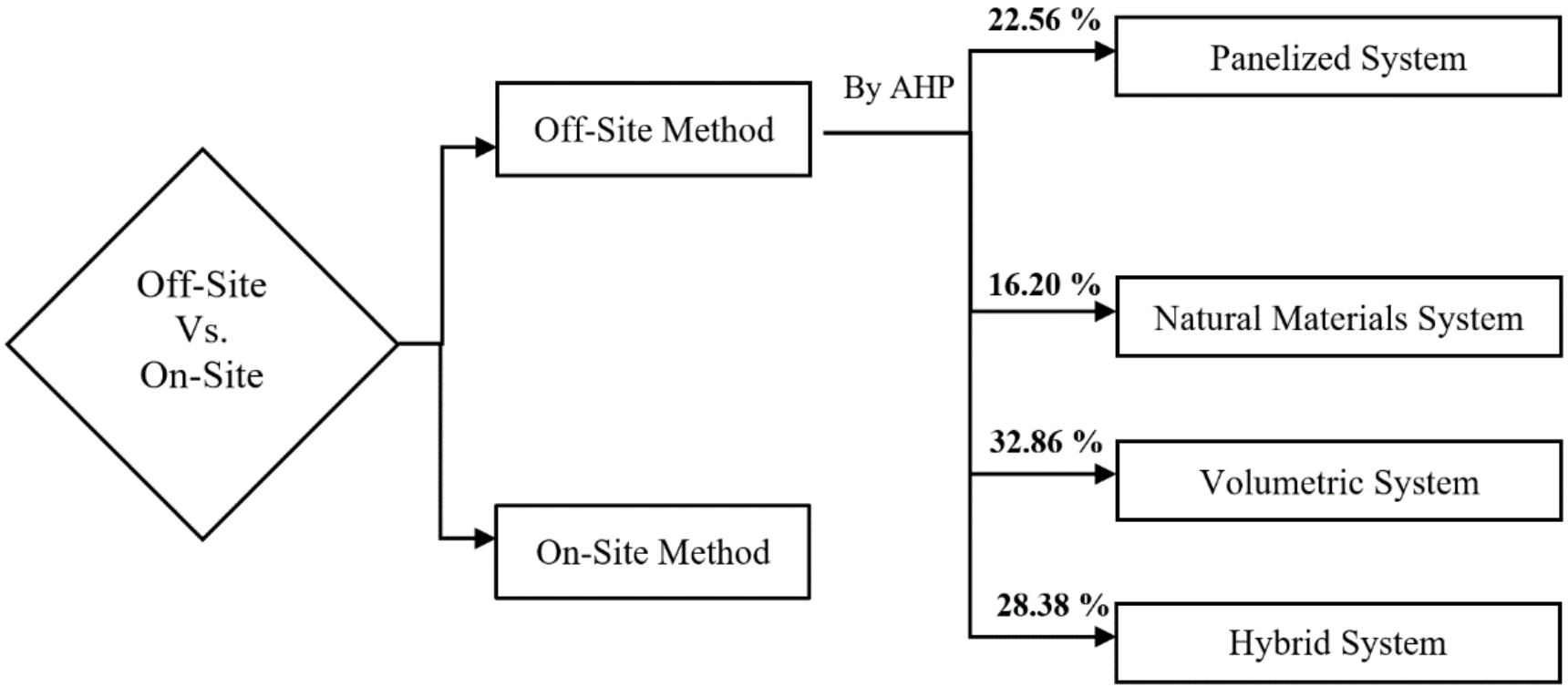
ANALYSIS AND DISCUSSION OF RESULTS (cont'd)

The weighted average rating for each decision alternative

Criteria	Cost	Time	Quality	Health and Safety	Sustainability	Process	Weighted Average Rating
Alternatives	0.09	0.05	0.21	0.33	0.19	0.12	
Panelized System	0.38	0.29	0.18	0.19	0.25	0.24	22.56 %
Natural System	0.17	0.06	0.11	0.21	0.22	0.07	16.20 %
Volumetric System	0.29	0.36	0.38	0.33	0.27	0.34	32.86 %
Hybrid System	0.17	0.30	0.33	0.27	0.26	0.35	28.38 %
Sum	1	1	1	1	1	1	100 %

- The **health and safety** factor affects mostly in making a decision followed by quality, sustainability, process, cost and time

ANALYSIS AND DISCUSSION OF RESULTS (cont'd)



The decision tree for selecting from the four off-site systems

- **Participants** prefer to opt for the volumetric systems as opposed to other systems such as natural materials systems, panelized systems, or hybrid systems

CONCLUSION AND RECOMMENDATIONS

1. A shift in the decision making process and a lean thinking approach should be applied to increase value in future off-site projects

2.
- Off-site practitioners are encouraged to invest in the lean philosophy to decrease the non-value adding tasks and to reduce cost and time, increase quality and safety, and deliver a sustainable building

3.
- Off-site practitioners should enhance communication among project stakeholders during the decision making process to explore different attributes of off-site systems

LIMITATIONS AND FUTURE WORK

The proposed study is limited to construction buildings in Lebanon and Syria	• The study can be also applied elsewhere once the goal, criteria and alternatives are identified
The study focuses on the main off-site categories	• Other off-site categories such as sub-assembly systems should be further studied
The study only covers important factors related to the decision making process	• Other factors and constraints such as transporting could be further considered

Thank you for your time !