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I, Nabi H Mortan, hereby submit this original work as part of the requirements for the
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Using Game Engines in Interactive Co-design

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Using Game Engines in Interactive Co-design

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Abstract

The methods typically used in architectural design practice where there are various project stakeholders, generally fail to provide enough interactivity among the parties involved in the design phase. Specifically, the current tools that are used in the co-design process are not able to bridge the gap between users, designers and researchers, since they lack real-time interactivity and are not able to be sufficiently understood, effectively tracked, or efficiently applied. The alternative tool proposed in this study, a tool to be developed using game engines, can be brought to life by following the guidelines of interactive co-design aspects outlined in this research. The features that need to be considered when developing this tool to ensure the effectiveness of the interactive co-design process are discussed in detail, specifically a real-time, multi-user capability for not only visualization, but also collaboration and manipulation. The framework proposed in this study will enable developers and programmers to take this to the next level by providing grounds for building such tools and ultimately seeking to allow the interactive co-design process to reach its true potential. With this tool and approach, all parties involved in the co-design process will have interfaces that will allow them to interact with the project design and with the other parties collaboratively, each in the way they feel most comfortable with, allowing the process to feel more welcoming and more enjoyable, and therefore creating more reliable, collective results.
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Preface

I always liked to tinker with computer software. This is how I have been able to learn many programs, since I have a talent that allows me to understand their working principles in a short time. Although software use was not an integrated part of my undergraduate program (at least with the variety that I knew how to use), my knowledge and use of them in my projects attracted attention from my classmates as well as my professors.

In the sophomore year of my undergraduate education, my view on architecture and design changed completely. In that year’s “Architectural Design” class project, we were supposed to design a “Water Sports Center”, to be located in my hometown, Izmir, Turkey, near the Aegean Sea shore of my university campus. I was excited that I was the first student to build a 1/20 model, complete with the material details. It was early in the semester and my professors said that my project was one of the best in the class at that point. But then something terrible happened at the end of the semester: I failed. All my knowledge on software was not enough to save this dreadful project. Or at least that’s what I thought.

According to my professors, I was not able to finish the project in sufficient detail. They claimed the project deserved more detail and sections, so that I had failed according to their criteria. They tried to convince me that if I made another project next year, I would be better to include such detail. I
never thought that a good project had to be also presented in such detail. I thought that great ideas would just speak for themselves. They knew that this was my first architectural project, and one of my professors said:

“The model that you had brought in the first week was better than this end-product. You should have been aware of the scale of your project. You should have been drawing sections, which allow you to integrate with the space. You lost control of your design.”

I was sure that my plan should not be to sit and cry that summer. With all these words circling in my head, I sat down at my desk, created the sketches of my old project that my professors had failed me on. I even modeled it in ArchiCAD, the first architectural software which I started to learn by myself, and also SketchUp, to create some more detailed interpretations of my conceptual drawings, and I honestly liked it. That summer, those words fired me up to learn many more software programs to create a design focused on “not losing control of the design,” “being aware of the scale,” and “integrating sections of a design.”

When I became a junior, then, I was aware of the different types of CAD modeling programs, which allowed me to create models in the different phases of the design. For instance, I could use Rhino to create smooth and curvilinear volumes in terms of understanding the mass, or SketchUp, to think about the levels of the building or vice versa. In the beginning of the concept, I always tried to put it on the computer and archive the process using CAD technology. Even when I sketched something I’d scan it in order to model it to see how it comes to life in 3D.
It is how the circulation and links work in the design, and on the site, and how it is experienced from eye-level that attracted my attention the most. It is easy to control model scale through CAD programs and build the real model according to that data. Of course, the technologies of laser cutting and CNC were also available, but they were out of my budget, and it was easy to create hand-made models in the design process.

That year, my professors from the Department started to work on two urban projects that they gave me a chance to join. One of them was the revitalization of the old square of Gaziemir, a county 8 kilometers away from the Izmir city center. There were lots of phases of the project, including the conceptual design, collecting and drawing the topography of the site, collecting the data of the community, which had a unique history, interviews with the residents, creating a full detailed 1/20 model and 3D models, perspective renderings, plans, elevations and sections. I worked on all of the phases of the project, except for talking with the community.

In the conceptual design process, we created two teams to be more efficient on timing. My professors liked to address the problems of the mass directly while we were creating them in CAD programs, which we had a chance to project on the wall and draw in the real-time for our professors to comment on. It was an interesting experience, like what I had seen with Frank Gehry’s office, in Sydney Pollack’s documentary.¹ Gehry would give some commands to his modeler, to change the shape of the model by hand. However I was modeling in SketchUp, in a 3D environment.

¹ Sketches of Frank Gehry, directed by Sydney Pollack (2006; Germany- USA, Sony Pictures Home Entertainment, August 22, 2006), DVD.
When I was working like a freelancer in architecture, I had worked with different architects in the design process, creating buildings in 3D. There was one architect who wanted me to use 3D Studio Max in his hotel design. I was able to create the model in 2 days, and it was ready to render. He said I should zoom in the render, so that he could look in the details. That would not be a problem, except that it was a high quality render, which had 1920x1080 pixels. He was intensely curious and impatient, so he asked me to turn the camera a little bit to the right. I nodded my head yes and laughed up my sleeve and thought about his question. "Did he want me to do it right now?" Then, he repeated:

"Please turn the camera a little bit to the left now; I want to see the other way."

But I had only the image in front of me. How was I supposed to turn the still image? Suddenly, a fascinating question comes to my mind. What if I could do it? What if it is possible to turn the renderings in real-time?

After some research, I discovered Lumion3D, an architectural visualization tool that was just released. It was not a real-time visualization program but it had a real-time interface to create renderings and animations. It was impressive to see a program that could render an HD image in 32 seconds with all details of lights and materials. And it was providing the same quality while editing the materials and lights. Intrigued by this, I wanted to see how such software had been created. I found out that the program utilized an old game engine called Arena. Therefore I started to wonder what else could be done with game engines in architecture.

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I know that the most important thing in a competition was time management, so I asked my professors if they wanted me to create some renders in “Lumion3D,” but they were skeptical and refused.

“What kind of a program is that? It makes the project something like a game.”

I also realized that, and asked this problem to myself: “Is there a way to create paths to use this technology in a different way?”

All of these experiences showed me that software tools play many roles in the design process, and especially when many people are involved in that process, they have a great potential to improve the collaborative workflow by better means of visualization, collaboration, and manipulation.

This year I realized that, several game engines are being used by various architectural firms to create animations/or experiences in the design process. Can game engines achieve such a huge responsibility to gather stakeholders for more complete interaction in the design process?
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1 Introduction

What ensures the success of a design process? Many answers can be given to this question; however the most important one would be staying true to the purpose of the design. Designing without a purpose and also in cases when there is a purpose but it is disregarded, causes all types of resources to be wasted, such as time, money, materials, etc. This can lead to frustration among stakeholders. One of the ways this can be prevented is by bringing experts and community members together throughout the design process.

The parties that work together are not always able to use a spoken common language. In these types of processes, there is a need to establish communication through various other means. For instance, while wanting to get feedback from townspeople regarding a project for a new town square, giving people an opportunity to express their feelings with visual means would encourage them to share their needs, instead of asking them to write pages of reviews, which would also cause more difficult processing.

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One of the ways by which this kind of situation can be handled is by co-design.\textsuperscript{7} Co-design is a way to create a path in the decision making process of a design project, for the participants, including both experts and users, to express their opinions and experiences via the given tools in order to design collaboratively for a purpose.

What is necessary for a good co-design process is for each participant to be able to visualize the design in order to help them with the decision making. It is also important to have some tools in order to collaborate, and let the participants manipulate the design in real time, seeing the changes in the design without any time lag.

It is important to take a look at commonly used tools in co-design to be able to judge their effectiveness and their deficiencies. Some examples of these tools include scaled models, commentary post-its, visual storyboards, persona cards, and bull’s-eye charts.\textsuperscript{8} The reason these means are commonly used is not because they are perfected tools, but because these have felt somewhat intuitive and easier to convey rather than complex computer interfaces. These conventional means have their share of flaws: they are not very capable of visualization, they are not accessible enough, and they do not offer enough flexibility for customization, for example. All these limitations lead to constrains on the quality of the interaction in co-design, and hence the results.


The lack of interactivity of the current tools needs to be remedied in order for co-design to reach its potential. For instance, the combination of tools and interfaces, such as game engines and motion controllers, which are most commonly used in game development, can enable interactivity in a more accessible way. This approach is called “experiencing” or “exploring” the virtual environment, where people can use an interface to generate ideas in more efficient and flexible ways. These interfaces are most commonly used in design processes in bigger scale and expensive projects. For instance, CAVE (Cave Automatic Virtual Environment) systems have already been used for decades for doing such interactions, but nowadays anyone can purchase those interfaces on the internet easily and cheaply (Figure 1).

Figure 1 – Cave Automatic Virtual Environment
High tech computers and programming with those interfaces can allow us to achieve an even better performance of interaction mainly because of their ability to create visualizations better than any other tool. Nowadays, high tech does not necessarily mean expensive. Yes, there are such tools, which are still under development that could foster even better performance in the long run. However since they are just being developed, it would be frustrating and labor intensive to develop with these tools. There are however cheaper alternatives as well. These grant users and developers more flexibility because they are readily available, and they potentially can be paired with existing tools to suit specific needs. Thus this thesis explores using game engines in this manner to provide people with a quite powerful alternative path to share ideas in the decision making phases of the co-design process.

Each of these tools, current and alternative, and their specific pros and cons, will be discussed in detail in Chapter 3.

The main inspiration for this study comes from my own experiences in architecture and design practice. From these experiences, reflecting on what can be the needed aspects of the interactive co-design process, three aspects come forward: (1) interactive visualization, (2) interactive collaboration and (3) interactive manipulation. An experiment will be demonstrated at the end of the Chapter 3. Experiences derived from the experiment, pertaining to these aspects and features, will be utilized in talking about the proposed tool of this research, using game engines in co-design, in Chapter 4.
In this approach, in order to understand how game engines could work in an interactive co-design process and what game engines can achieve and push further in architecture, it is necessary to first of all, to explore the basic characteristics and potentials of the co-design process itself.
2 Review of Co-design

Bringing concepts and ideas further requires understanding their history first. Therefore, it is important to take a look at how co-design has emerged, and what are the stages it has passed through to become what it is today. In this section, the history of co-design, its various definitions through time, and the current tools used in co-design will be examined. The current tools will be critiqued through a real life example. Departing from the strengths and weaknesses of these current tools, alternative tools will be discussed for their potential uses in co-design. In the end of the section, three aspects of interactive co-design, which will assist in the way we think about various tools and their effectiveness in co-design, will be suggested and discussed in detail.

2.1. Review of Participation in Co-Design

When we trace co-design back in time, we arrive at an idea that was coined in the 1960s in Sweden. This idea is in essence very similar to co-design: including the community in the process of making important decisions about the city. The reason there was a need for involving citizens in these decisions was that they were getting frustrated about their city being shaped by the architect, in a
way that they did not agree with. This was referred to as participation; however it was not formalized as a method.\textsuperscript{9}

In 1970, Scandinavians welcomed the idea of participation, with the name “cooperative design,” in order to enhance human-computer interaction at their workplaces.\textsuperscript{10} The main thinking was to allow stakeholders to share valuable expertise and experiences. When it arrived in the US, the term was deemed insufficient to capture the community notion of the concept “participation.” Thus, in order to nourish its full purpose, it was changed to “participatory design.”

Chronologically, it makes sense to start talking about co-design with the 1960s idea of participation. However, it can be said that participatory design is the real ancestor of co-design due to the fact that it embraces the inclusion of the community. Additionally, because it is a formal method, it is possible to be built upon. Thus, it is worthwhile to take a closer look at participatory design in order to understand how the concept of “co-design” came to be.

It is possible to see that no matter what it has been called, the participation level has always changed when practicing participatory design in architecture. Fredrik Wulz classified these different levels as seven forms of participation in his 1986 work. In his study he identifies each level and gives detailed explanations of them with examples, in order to compare and contrast them, and also to show how much architects allow other stakeholders’ involvement in each.


\textsuperscript{10} Susanne Bødker, Creating conditions for participation: Conflicts and resources in systems design, Human Computer Interaction 11(3), 215-236
Wulz’s (1986) seven forms of participation are as follows: (1) representation, (2) questionary, (3) regionalism, (4) dialogue, (5) alternative, (6) co-decision and (7) self-decision.\textsuperscript{11} Although these 7 forms represent different levels of involvement, as Wulz would also agree, these do not mean that architects can be classified in these terms with their styles.\textsuperscript{12} On the contrary, it is possible to see these forms in the different areas of the co-design process. Therefore, looking through the lens of the three aspects of co-design, it is possible to further group these seven under three: representation and alternative under visualization; questionary, regionalism and dialogue under collaboration; co-decision and self-decision under manipulation.

In the aspect of visualization, the main goal is to allow stakeholders to easily observe and experience what the final design will look and/or feel like. This can be done either with the final look of the design or with various conceptual depictions. According to Wulz’s classification, representation is the one by which the architect is responsible for researching the people’s daily life, who will be the users of the design, and then showing a design without any interaction with them.\textsuperscript{13} Alternative visualization, on the other hand, involves architects showing several versions of site plans, plans, sections, or concepts of the design to users in order to see which ones they would prefer.\textsuperscript{14}

Collaboration is the aspect of co-design that allows more communication among parties involved in the design process by experience, knowledge and expertise sharing. Questionary looks at the preferences of users in a more analytical way, assuming that what most people report to be important

\textsuperscript{11} Wulz, “The Concept of Participation.” 155.
\textsuperscript{12} Ibid, 161,162.
\textsuperscript{13} Ibid, 155.
\textsuperscript{14} Ibid, 158.
should be the most important thing for everybody.\textsuperscript{15} Regionalism involves the daily lives of people as well as the local culture in order to preserve the cultural and symbolic aspects of the area.\textsuperscript{16} Dialogue entails having conversations with the stakeholders about the design in the early phase of the design process.\textsuperscript{17} In each of these, although feedback is gathered from the stakeholders, the final decision belongs to the architect.

Thirdly, manipulation allows stakeholders to change and modify the media that the architect provides. Being able to express thoughts and comments on the design in a more intuitive and tangible way, manipulation grants stakeholders a say in the final decisions of the design process. This is especially important because it allows stakeholders to demonstrate their expertise in a more direct way.\textsuperscript{18} Co-decision means that the stakeholders that are involved in the design process are present at all phases of the project and there is a mutual understanding and consent among the architect and the stakeholders about each of their involvements.\textsuperscript{19} Self-decision can be thought of as the most extreme involvement of the user.\textsuperscript{20} The architect basically serves the needs and wants of whomever the user is, not considering any regulations other than basic community safety and security rules.

Departing from the discussion above, it is possible to see that even if participatory design is practiced in the way that Wulz has defined, the gap between the architect and the other stakeholders remains. To overcome this gap, it is apparent that a method that gives the stakeholders more say and also that is more interactive is necessary. It is also possible to see that participatory design has a “design for

\textsuperscript{15} Wulz, “The Concept of Participation.”, 155,156.
\textsuperscript{16} Ibid, 157.
\textsuperscript{17} Ibid, 158.
\textsuperscript{18} Ibid.
\textsuperscript{19} Ibid, 158,159.
\textsuperscript{20} Ibid, 159-161.
people” approach, meaning that it is still mostly the architect who has the longest say in the design process.

Among Wulz’s forms of participation, it is apparent that the one that provides the most advantages without going to the extremes is the co-decision, as it provides the most involvement on the stakeholders’ side while still maintaining the architect’s expertise. It can be thought that co-decision is what has inspired the concept of co-design. Co-design will be explored in more detail in the following section.

2.2. Defining Co-Design and Its Tangents

When the literature on co-design is examined, it is possible to get the idea that the field is somewhat in disarray. This has been mainly caused by the desire to take the core concept of co-design, and distinguish other terms that are slightly different than co-design. Thus, although one fails to find mountains of work on specifically co-design, it is possible to think that the mountains are there in the form of tangents of the term. Therefore, it is worthwhile to take a look at some of these tangents while researching co-design. In this section, co-design will be defined and also post design, co-creation and generative tools will be discussed.

As noted in the editorial of *CoDesign Journal* in 2005, the term “codesigning” first appeared in a conference in Coventry, UK, in 2000. 21 In the conference, the attendees agreed that all the terms such as participatory design, community design, user-centered design, etc., needed to be gathered under one roof in order to better make use of the distinctive virtues of each term. Although there is a

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5 year lag between the founding of the concept and the publication of this editorial, the *CoDesign Journals* act of recognizing the term allowed it to gain certain recognition.

Elizabeth N.B. Sanders is one of the most dedicated researchers of co-design. It is possible to see her dedication to the field with the fact that she is the Associate Editor of *CoDesign Journal*, the very journal that launched the term co-design in the first place. It is not by chance that she came to be interested in co-design. Her journey with co-design actually begins a little earlier than the UK Coventry Conference.

In 1999, Sanders had already defined the term “post design,” which lets users and stakeholders interact directly. She said that it is important to see 3 interactions in this type of design, what users “(1) say, (2) make, and (3) do” (Figure 2).

![Diagram](image)

**Figure 2 – Sanders’ say, do, make approach**

In 2008, she noted that the new designs are focused on purposes, not professions. She created mass model objects to use in co-creation, that she called “generative tools.” These tools are presented to

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people for brainstorming about the organization of the space, assuming users to be the best organizers of their own spaces in the beginning of a design process. Figure 3 shows stakeholders using these generative tools provided by Sanders.26

![Figure 3 – Stakeholders using generative tools](image)

Departing from her previous research, in 2009, Sanders with co-author Simons, defined co-creation and co-design in the following sentences:

“Co-creation is a very broad term with a broad range of applications. We define co-creation as any act of collective creativity that is experienced jointly by two or more people. How is co-creation different from collaboration? It is a special case of collaboration where the intent is to create something that is not known in advance. The concept of co-design is directly related to co-creation. By co-design we refer to collective creativity as it is applied across the whole span of a design process. By these definitions, co-design is a specific instance of co-creation.”27 (See Figure 4)

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25 Elizabeth Sanders, "Co-creation and the new landscapes of design": 15
26 Ibid, 14.
In order for the co-design to be effective, Sanders defines co-design space and identifies its critical elements. In this definition she firstly underlines the need to clear the physical space from all negative stimuli in order for the stakeholders to feel comfortable within the co-design space. Additionally, she stresses the importance of time management and optimization to avoid wasting time and causing frustration. In this definition of the co-design space, Sanders notes that the physical space needs to be specifically prepared for the stakeholders to feel like equals within the space and therefore allowing them to speak their minds more freely. As the co-design space is a particularly important element for this study, I will be making frequent references to it throughout the text.

Although I include a small portion of the extant definitions of co-design, it is possible to see that there is a great proliferation of concepts in the field. Therefore, I believe before venturing further, it will be beneficial to briefly summarize again what co-design is all about: Co-design is a way to create a path in the decision making process of a design project, by which the participants, both experts and/or users, can express their opinions and/or experiences via the given tools in order to design for a purpose.

28 Sanders and Westerlund, “Experiencing, Exploring and Experimenting in and with Co-Design Spaces.”
As it can also be seen in the summary above, although all the parts making up the co-design process are important, the most critical is the tools to be used. These tools are either the enabler or the barrier of clear, efficient and effective communication among parties. In order to reach the promise of this study, to propose a new tool, it is necessary to examine the current tools used in the co-design process. This approach will also demonstrate why new tools are necessary to be adopted in the co-design process.
3 Tools in Co-Design

The tools of co-design have not always been unique tools that have been created for the process, rather it has internalized tools used in other sciences or fields to reap the benefits. When dedicated tools were created for co-design, this was mostly in the form of taking potentially beneficial tools and customizing them to suit the specific needs of the co-design process; such as 2D visuals, 3D mock-ups etc. In this section, the tools that are most commonly used in co-design will be discussed in order to understand their virtues and limitations. Furthermore, the proposed alternative tools to be brought into co-design will also be examined, in order to see how these tools would help mitigate the problems of the conventional tools used.

3.1. Conventional Tools

When enumerating all the different types of tools that are currently used in co-design, it is possible to see that although they are many in number; they can also be grouped under three main groups: tangible tools, conversation-based tools, and action-based tools.

Tangible tools include pre-shaped visuals that are made of paper, foam, etc., that people can hold, draw on, or cut/break apart, and paste in other places to create mind-maps to express opinions.

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Examples of these tools can be given as timelines, bull’s-eye charts, and reconfigurable models made of foam, Legos or other materials (Figures 5, 6, 7).

![Image](image_url)

Figure 5 - Top image, timeline / Figure 6 – Bottom left image, bull’s-eye / Figure 7 – Bottom right image, reconfigurable model

Conversation-based tools can be thought of as the tools that include voicing of ideas via talking, telling or explaining. These aim at sharing real life experiences that have been recorded by means of keeping diaries, taking short videos, etc., and shared with the group in the co-design spaces.

Action-based tools require some sort of action to be done by the stakeholders in order to understand the real life situations related with the subject of the design. Improvisation by the stakeholders can be one example of action-based tools, to experience the different types of naturally occurring instances in the related context. Another example can be given as game boards. Game boards are used,
especially when working on topics that are suspected to be boring or exhausting (either physically and/or psychologically), to make the process more game-like and engaging.

It is also necessary to take a look at specific examples and applications of these tools to fully appreciate what each of these three groups entail as well as their strengths and weaknesses. A better understanding of these strengths and weaknesses will help users of these tools to better recognize their role in the overall co-design process. This understanding would help the users of the tools to be ready to counter any problems that may arise due to the characteristics of those tools. Understanding these tools also allows alternative tools to be built in such a way that complements the areas where the common tools fail. As we have seen in the above discussion and examples, tools of co-design can be very engaging, effective and interesting when creatively customized to fit the needs of the project at hand. However, these tools are not without their weaknesses.

Before moving on to the alternative tools, it would be worthwhile to visit a real life example, where we can see in action the strengths and weaknesses identified above. This will allow us to understand some of the problems that were faced because of the tools utilized, and also to be able to interpret how these could have been prevented. This example will examine the co-design tools utilized in the design phase of the Gaziemir Abdullah Arda Square project that I was involved in. This process included individual interviews with stakeholders, group meetings, and visual presentations to locals. The project mainly was concerned about revitalization of the main square in the area, which had lost its functionality and its variety over time.
3.1.1. Conversation based tools

The main conversation-based tool we utilized was individual interviews. These included asking questions to each stakeholder in the area, and allowed us to understand the old rituals of Seidiköy in their environment. This approach was carried out with a regionalist and dialogue approach, using Wulz’s terminology.

When we visited the site for exploration, we were examining the locals’ daily life routines. This helped us to understand how they live, what their habits are, and what they really enjoy and dislike about the current state of the square. However, with the interviews we have conducted, we were able to add to our observations of the daily life with the rich contextual information we gathered from the locals.

In time, we also saw that it was valuable for us to spend that face-to-face time with most locals, as the project required us to spend extended time in the square. This extended time was made more pleasant by the fact that the locals recognized us and did not feel threatened by our presence. Without this kind of immersive exposure, they could easily have had doubts such as “are they here to demolish our houses” and such questions, without knowing how the area was planned to be improved without them being displaced.

It also made sense as a first step to have this kind of free form interviews, as it did not put certain limits around the discussion. As we did not provide any proposals or any conceptual ideas to them in the first place, the locals we spoke to were not bound by the suggestions we would be making.
Instead, they were able to freely comment on what they were feeling/thinking about the area, how they thought it could be improved and what needed to be preserved.

Although face-to-face interviews enjoy several advantages, it also has some points that could hinder the responses gotten from the locals. One such concern would be about the possible effect of not being able to share socially undesirable actions or thoughts. For instance, after spending some time in the project with the local men, we realized that the real reason men hung out in the kahve\textsuperscript{30} was only because there were not many local women passing through the square in their daily routine, so they could relax and hang out with friends without being disturbed by their wives. This situation is something we would have never thought about on our own. However, it was also very hard to extract from the local men via face-to-face interviews, probably because they thought we would think negatively about them. Thus it was by chance that we finally understood this. However, one should always expect that there can be such unexpected true stories in people’s minds, and it should be tried to be captured by less invasive methods such as leaving comment/suggestion boxes so people can write more freely.

It should also be noted that the sincerity put forth by face-to-face interviews also makes it impossible for locals to express ideas anonymously. In cases where this may be an issue, tools that do offer anonymity should be preferred.

\textsuperscript{30} Kahve is a traditional café that mostly men hang out to drink tea/coffee and play card games, backgammon and rummikub in Turkey.
3.1.2. Action based tools

When talking about a potential project and asking locals’ opinions regarding the details of the design, what you ask people to basically do is for them to think about the area in terms of its future state and comment on how they would like living there. Therefore, rather than asking this directly, it makes sense to use media like scenario based role playing and/or improvisation, as Sanders\textsuperscript{31} also suggests in her framework.

The main action-based tool used at Gaziemir Abdullah Arda project was almost like a scenario based role playing that was conducted in group meetings. The locals who attended these meetings were given certain circumstances, and they were asked to react to these situations. When the situation given was an important enough issue, the discussion included most of the attendees, which allowed us to gain great insights about what they would think about these alternate future plans. For instance, when talking about the future of the square regarding its shape (whether to change it or preserve the current one), it was mentioned that what they really cared about was the size of it rather than the shape since the municipality was using this area to give Ramadan dinners to the locals and also for important gatherings (Figures 8 and 9).

\textsuperscript{31} Sanders et al., “A Framework for Organizing the Tools and Techniques of Participatory Design.”
However good it was to apply these tools, it is important to recognize the points where it was very strong and also the points where the technique is lacking, in order to better manage the situation. For instance, it is a great opportunity to have a mass of people belonging to the same group rather than an individual in terms of creating a brainstorming co-design space.

In the action-based tools, it is also an important notion that with the use of board games and other types of more enjoyable media (such as role playing or card games), the meetings held become more fun for the attendees. And it is generally thought that when people have fun while learning (or performing an activity), the results are more effective. However, this may be a double-edged sword. People may also have a hard time transferring what they see as a game into what these would correspond to in their daily lives. For instance, when presented with a set of game rules, they play that game according to those rules, set forth by the researcher. However if in any way, the game or the rules feel synthetic to the participants, they may feel that they cannot express their thoughts freely and that they are bound by the rules of the game.

It is noteworthy to mention that this group of people is a naturally formed group of locals, whether we were there or not. Thus it is important to keep in mind that the researcher and the designer enters into this already existing group to conduct research and use various tools to assess thoughts and feelings. Thus it should be considered that once the research/design team leaves, the group will remain in the area and their social interactions will continue. Thinking about this, people may have reservations about sharing thoughts that they may think to be different than those of others, or maybe thoughts on sensitive issues, in order to resume their social interactions without interruptions.
3.1.3. Tangible tools

The main tangible tools used in Gaziemir Abdullah Arda project were scale models, 3D renderings, plans and sections. Although there are a variety of tools used in this group, it is possible to see that their advantages and disadvantages are related to each other since they all depict the same subject, just in different forms.

One advantage pertains to the depicting of the same subjects in different forms. Because the observer is able to look at the design in different detail levels, one can think that this allows a variety of people to be able to get something out of it. For instance, in the Gaziemir Project, while the technical staff was interested in technical drawings, spent more time on the plans and sections, and appreciated these visuals, the locals enjoyed other visuals more such as the 3D renderings and the scale models.

Especially when compared to the other groups of tools, tangible tools have the advantage of being visual. There is less imagination needed to be able to understand what they demonstrate, though the level of visualization they provide will be discussed in more detail when talking about the game engines as alternative tools. The effect of seeing these visuals is twofold: for the ones who are used to these types of media, they may have an easier time picturing themselves in the illustrated environment; on the other hand those people for whom these visuals are a new medium, may be drawn more to the image itself, rather than to the design that the image shows. Therefore it becomes extremely important which of these is true, in order to understand whether the design is well received by the observer or not. For instance in the project, it was made apparent to us that the scaled model attracted stakeholders visually. However they were having trouble interpreting where
their houses and shops were located in the scaled model, because they were not used to seeing such media. Both the interest and the frustration of the locals can be seen in Figure 10.

![Figure 10 – Locals of Seidiköy in Gaziemir Abdullah Arda Square observing the scaled model of our project](image)

One of the most frustrating disadvantages of such tools is that they have a pre-defined point of view, be it a still image or an animation. It should be remembered that even if the medium used is an animation, it still follows a pre-determined route within the 3D space of the design. Therefore, whatever the designer has decided to capture, that is what the observers are bound to look at. They cannot for instance demand to see the “other side” of the building, if it is not already provided.

In most cases, these types of tools are not open to manipulation by hand by the stakeholders. Even in cases where this is possible, for instance models with replaceable units, there are two issues that arise. One is that the stakeholder is still bound by the capabilities of the material provided, and
secondly, the scaling of the model makes people feel like giants, managing the design, rather than thinking of themselves as the locals who will be living in the design in their daily lives.

One last disadvantage of tangible tools is that there is no guarantee as to how much the stakeholder manages to think like they were living in the design, while making comments on what they like and do not like. It is totally up to their creativity and their capability to visualize themselves within the designed environment.

Each of the tool groups Sanders identifies, sets out to serve more than one purpose. However, this is exactly where problems with the conventional tools arise. Although these tools can serve different goals, they do not allow the flow among these varieties of goals. This is why, identifying each need and seeking to use proper tools to accommodate each of them and defining the flows among these aspects would be a more appropriate approach for the co-design process. When relying on a single tool to answer the different needs of stakeholders, everybody is forced to use the same interface. This might not be the best case, as it might be overly complex/simplistic to some, and they may not feel comfortable using the means provided to express opinions. A first step towards such an approach came from Sanders with her “say, do, and make.”32 This approach represents the different actions stakeholders can choose to perform in order to communicate their thoughts and comments. Although this approach is able to capture the variety of actions that can be used, it still does not provide or identify a flow among these actions. Thus it is not helpful in developing holistic solutions to the alternative tools problem. While Sanders allows us to understand the different actions that

should be hosted in the co-design process, Wulz provides us with an understanding of the different levels of participation and the flow that exists among these. He achieves this by stating while there is such a variety of levels of participation that can be sought by architects, this is in no way trying to classify architects. On the contrary he notes that these different levels will be triggered by the specific needs of the design project at hand. And thus there is a relationship, a flow among these different levels that should be recognized and should be included in tools of co-design.

From the review of the previous section, we can summarize the limits of current tools into three areas. These three areas and the remedies (Figure 11) for each of these follow:

- Lack of interaction with experts/community → Interactive visualization
- Inefficient, untraceable and uncontrolled data → Interactive collaboration
- Unable to make changes for their needs → Interactive manipulation

Figure 11 – The three aspects of interactive co-design
Figure 12 – The flow among these features

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33 Wulz, “The Concept of Participation.”
The interactivity within each of these remedies is critical because it is what current tools lack most, as they fail to carry this interactivity throughout the co-design process. It is the interactivity among visualization, collaboration, and manipulation that makes the interactive co-design process possible (Figure 12). When there is such disconnection among these three aspects of the process, the interactivity and thus co-design might not work with its best potential. However, this should not mean that we should abandon the conventional tools of co-design. On the contrary, we should recognize their merits and demerits and while continuing to use these tools for their merits, compensate for their demerits with alternate tools.

These three aspects would need to be achieved with alternative tools such as Building Information Modeling (BIM) tools or game engines. It is important to note here that whichever alternative tool is utilized, it would need to be combined properly with the conventional tools through an interface. Therefore in order to better compensate for the demerits of conventional tools, BIM tools and game engines will be discussed in the next section, in terms of how they would be able to counterbalance these, and therefore which one would be a better alternative tool.

**3.2. Alternative Co-design Tools**

As we have seen in the current tools, there is a general theme that the tools are very dependent upon the skills of the researcher and/or the designer and the results gathered from the stakeholders depend highly on how much they can visualize themselves in the design. Therefore it can be seen that alternative tools that would be able to alleviate these dependencies would need to be formed or brought into the co-design process. The dependency on the skills of the researcher and the designer
may never truly be broken, as these skills are the enabler of such tools. However alternative tools can help observers with understanding the design through their own terms, not only the terms put forth by the architect/designer.

While it may not be easy for the stakeholders to understand what is offered by the tools used by the designer, it is not always easy for the designer to convey to the stakeholders the capabilities and limitations of the tools he/she fluently uses while designing. In these cases, the communication among the designer and the stakeholders is bounded by the capabilities and limitations of the tools utilized. Ironically, a tool’s sole purpose is to bridge the gap among different stakeholders and the designer. Therefore it is apparent that tools that allow more flexibility are required to be used in the co-design process such as BIM tools or game engines.

BIM tools and game engines can be examined under four groups according to their uses by designers in the co-design process: creation, presentation, interpretation and feedback.

Both BIM tools and game engines may or may not be utilized in all these different uses, and sometimes they can be used together to serve these needs. However, it is also worth mentioning that the areas in which BIM tools and game engines excel are different. Understanding these best performing areas for both kinds of tools is important in order to compare these two tools. In the following sections, both tools will be examined through examples in order to identify which uses are best realized with effectiveness and more interactivity by which tool in the co-design process.
3.2.1. BIM tools as alternative co-design tools

BIM tools are mostly used for creating 2D computer aided design (CAD) drawings and 3D models of designs simultaneously in various fields such as design, architecture, and engineering. These are formed by two possible ways. One of the methods is to input a series of measurements which then the software translates into a 3D object. The other way is to utilize ready-made shapes from the software’s object library (cubes, pyramids, windows, door, walls, roof or any 3D representation of an object that is desired to be placed in the design). The resulting model can be viewed as any type of drawing and/or a 3D model. The newer versions of some of the software have started to incorporate different technologies such as showing energy efficiency of the design in real time, printing out the model from 3D printers, and so on. Some examples of BIM tools include ArchiCAD, SketchUp, 3ds Max, Revit, and Ecotect.

For decades, BIM tools have been mostly used by designers, architects, and engineers for creating technical drawings and for supporting the production process. BIM tools and software are also starting to be recognized as possible alternative tools to be used in co-design, in the last few years. These tools provide some advantages above and beyond conventional tools of co-design as they allow for a more efficient pipeline in the creation, presentation, interpretation and the feedback phases. These tools also would allow easier conveying of ideas and communication with the stakeholders in the co-design space.

Especially with the ability to get both 2D and 3D representations with the time investment of setting up only the 2D details, BIM tools provide a time advantage like no conventional tool. This also allows the ability to switch back and forth from 2D to 3D, which in turn makes real time
designing in 3D possible. As will be discussed in the examples in this section, although this ease of transference is a desirable feature, it is not possible to be used in the co-design space. The reasons for this are several: the interface for these software packages are usually intimidatingly complex to the people who do not know how to use them, the setting up of the desired change in the design seen on screen can be time consuming, and lastly the full quality rendering of the current state of the design is impossible to be gotten in the time frame allowed by the co-design space (sometimes taking more than 12 hours).

Exemplifying the above discussion through personal experiences will allow me to demonstrate the real frustrations and communication gap that can occur because of the limitations of the utilized tools. The first example stresses the inflexibility of BIM tools’ presentation ability. In a project that I took part in, we were designing a municipality building. When it was time to do a presentation of the design, it was decided to include an animation of the building and its surroundings. It was going to be a 30 seconds long animation. After getting the animation ready for rendering, the estimated completion time information provided by the software showed 5 hours, which was an okay time for the task. However it took 12 hours to complete. Although it took so long to render, it was well worth it because the attention was on the looping animation on the screen as we were presenting other materials as well (Figure 13). However, when I think about it now, if the clients had wanted to see any other detail in such a visual way provided by the animation, we would not be able to complete it in the time allocated within the co-design space. We would need to hold another meeting for the new version, and maybe a couple of more meetings, until there was agreement on the design. It is very clearly seen that this type of limitation leads to time loss. On the other hand, if
we were able to do these changes in real time within the co-design space, then this would definitely be a more efficient process in terms of time management, and also would be a much more pleasant experience for all the stakeholders as well as the designer.

![Figure 13 – On the Left: The Scale Model of Gaziemir Square Project / On the Right: The attentions are on the animation during the municipality building design presentation](image)

The second example appreciates the variety of stakeholders that are involved in the co-design process and displays how this variety is not able to be embraced with the BIM tools in terms of the interpretability of the materials created with these tools. It should always be kept in mind that in the co-design process, the variety of points of view put forth by the stakeholders is something to be acknowledged, as this variety is the very thing that makes the co-design process what it is. With these different viewpoints, come different expectations for the way the design is presented. For instance, in a project I was working on regarding a public urban academy, I was asked to include in the presentation different elements of the design, such as canopy, circulations, materials, etc., separately. However I had a hard time preparing these, as each required a different representation technique.
For the circulations, I used a more abstract version of the mass, while using a rendered version of the design with textures for demonstrating the materials used. When I think now that there are game engines that are able to do these kinds of tasks with the click of a button, I wasted so much time trying to do these with BIM tools. As can be seen from this example, to be able to deliver on the needs of stakeholders, it is critical that the tools utilized can provide the ability to create different representations by the designer in the co-design space in real time.

The last example demonstrates BIM tools’ lack of ease in the feedback loop process. It can be frustrating to not be able to change the point of view in real time with BIM tools while preserving presentation quality. I was working on a hotel building project at the time and in the rendering, I had used 3ds Max, which had the latest features provided by any software in the market at the time. I was able to present texture quality nicely and details of lighting were the best. While presenting the rendered images to the client, he appreciated the quality of the images. Yet he wanted to see the design from another angle and asked me if I could turn the camera of the rendering a little bit to the left. I am totally sure that he did know it was an image. However, there was no way for me to turn a static image as if it was a 3d model while preserving the quality of the rendering with the lights and the textures, with the BIM tool that I was using. Therefore even if I had showed him the angle he desired to see from the 3D model, without the lighting and the textures rendered, he would not be able to truly judge the design.

To sum up the review of BIM tools, while they help somewhat with the visualization aspect, they completely fail to deliver on collaboration and manipulation. Perhaps the most frustrating feature of BIM tools is that they lack the interactive feedback loop. Without such a feature in place, once
feedback is gathered, the time required in between iterations is long enough to require the
disassembly of the current co-design space and reconvening at another time. The iterations may not
stop there though. As long as feedback that affects the design is gathered in sessions, the iterations
will need to continue until either a consensus is reached or one of the parties give up. As can be seen,
this is not a wanted situation in the co-design space. Thus it is possible to conclude that BIM tools
are not sufficient as a co-design tool on their own. However, before abandoning BIM tools
altogether and venturing forth to find other alternative tools, it would be fruitful to spend a little bit
more time on BIM tools to identify which parts of them can still contribute to the co-design process
and what are the remaining necessities that need to be fulfilled by other alternative tools.

Wondering whether such software that can handle such a task existed, I did some research and found
out that there is actually a lot of software that do have that ability. For instance, game engines can be
considered as an alternative tool, per the discussion of an example provided below, it is possible to
see instances where BIM tools and game engines have been utilized in collaboration, to reach result
not attainable by either tool on their own.

In terms of creating visualizations, one of the most successful BIM tools is Revit with Autodesk
Showcase. It differentiates itself from its rival BIM tools, as it allows for easy activation of its game
engine features (provided by Revit), such as navigation, texture and material modification, and its
three different representation techniques (conceptual, interactive, and realistic). As it is the case with

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34 Autodesk Showcase & Revit Visualization example: [http://www.youtube.com/watch?v=BAQo4-ULi1w](http://www.youtube.com/watch?v=BAQo4-ULi1w) (Last accessed: November, 2013)
other BIM tools, this hybrid tool also does not allow for an interactive collaboration and
manipulation.

Another example of this can be given as the Turntool\textsuperscript{35} software, a 3Ds Max plugin, which allows
the importing of 3D models into a real-time environment created with a game engine called Unity.
This plugin guides 3ds Max designers to import (transfer) their work in a customizable 3D
environment in order to provide stakeholders an interface by which they can interact with the object
and change certain aspects of it such as colors and textures. The software also gives programmers a
chance to create custom interfaces by allowing them to access the source code.

Another feature of this software can be thought as good and also bad; it has a browser support that
allows Turntool to provide the presentation in any platform, however this also means that if the
interface is run in a window (as opposed to full screen, which allows for a more immersive
experience), it will detach the stakeholders from the 3D representation (Figure 14). While a small
amount of modification can be done (as can be seen in the right side of Figure 14), this is hardly an
interactive manipulation process as it includes only a few options to change and there is no creativity
involved, making the manipulation capabilities very rigid.

\textsuperscript{35} Turntool Software Website: \url{http://www.turntool.com/} (Last accessed: December 18, 2013).
As can be seen in the above discussions of examples, game engines offer promising features to be considered as alternative tools for the interactive co-design process. In order to truly decide whether game engines are the alternative tool that is the missing ingredient, it is necessary to take a detailed look at them.

As described in the above discussions, BIM tools have their share of useful features, but when used as co-design tools they lack in visualization, collaboration, and manipulation. As also can be seen in the above discussion, BIM tools can incorporate small portions of game engine interactions. However because it has more of a cutting corners approach, even when they are used in unison, they cannot grasp and appreciate the full capabilities of game engines. On the other hand, when game engines are used in a more holistic manner, it will become possible to use this potential in a more effective way, creating a more powerful interactive co-design tool.
3.2.2. Game Engines as Alternative Co-design Tools

Game engine technology provides the basic rules and principles required to develop video games within a package that also allows the creation of libraries in order to avoid task duplication. Some of the most popular examples of game engines include Unreal Development Kit (UDK), Unity 3D, CryEngine and Blender Game Engine. Although these various game engines have some differences in the way their workflows function, there really is no preference of one over others. To demonstrate this, in this section and also in Chapter 4 when discussing game engines’ role in the creation of an interactive co-design tool in detail, examples regarding different game engines will be provided.

The most important advantage of game engines over BIM tools is that they can, in real-time, compensate for all the limitations of BIM tools. As will be discussed in greater detail in Chapter 4, game engines provide extensive possibilities for enabling interactive visualization, collaboration, and manipulation and thus should definitely be considered as an alternative tool for the interactive co-design process; they also embrace the convertibility between themselves and BIM tools.

Utilizing game engines in the interactive co-design process requires the creation of a tool with that game engine as it is not able to satisfy all the necessary requirements as is. The best way to demonstrate why this is the case is to look at this issue through an example. HKS Inc., an

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36 Definition based on: http://gameindustry.about.com/od/resources/g/Game-Engine.htm (Last accessed: November 02, 2013)
37 Unreal Development Kit (UDK) Website: http://www.udk.com (Last accessed: March 27, 2014)
38 Unity 3D Website: http://www.unity3d.com (Last accessed: March 27, 2014)
39 Crytek CryEngine Website: http://www.crytek.com/cryengine (Last accessed: December 21, 2013)
40 Blender Website: http://www.blender.org (Last accessed: February 10, 2014)
architectural firm used real time visuals to present their Dallas Cowboy Stadium. In fact, they bought the game engine called Unreal Development Kit (UDK) to create their own tools, in order to make use of real time presentations, because the free of charge version could not handle their complex structure in real-time. In the process of exploring the entire stadium model in the game engine, they identified a problem with the locations of billboards together with stakeholders, with the use of first person view, and thus they were able to manipulate the design to overcome this issue. Without such an insight, the design would be built with this problem still existing, and there would be frustration among the people that came to watch the games, because the billboards would be blocking some people’s view. Thus, with the use of this tool, they were able to prevent such frustration and the related costs that would entail having to change the locations of the billboards after the construction has been completed. Although this example is illustrating visualization, and not the full range of co-design activities, it still provides a good basis on which to build the proposed approach, as it proves that game engines can be successfully used in real time while interacting with stakeholders.

The potential for game engines into the co-design process is what has mainly fueled this research. In the following section, game engines will be introduced and their potential benefits for the co-design process will be discussed.

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3.3. Useful features that arose from a failed experiment

This experiment was conducted within a visualization class I was attending. The experiment required us to make use of either a BIM tool or a game engine to create a visualization demonstration. Per my interest in game engines, I decided to work with this medium with two other people. Within the team, I was the only one who could use UDK game engine and therefore the responsibilities within the team was for the others to design their buildings and for me to create the environment in which these buildings would be located.

The biggest challenge I had in this process was to understand the design and the designer and create a suitable environment in UDK. I was the one who orchestrated the conversion formats of the designs each designer was working on, because they were using different BIM tools (Revit and Rhino), and I needed to import these into the game engine. At first I struggled with placing these designs into the 3D topography I had created. However this has taught me a good workflow by which these tasks can be completed more effectively. A workflow of importing 3D topography from any BIM tool into UDK can be listed in following steps: 1) Open the topography in 3DsMAX; 2) Render height map through settings; 3) Save height map as an image; 4) Convert height map with a height map converter; 5) Import height map in UDK with the topography tool.

The only challenge to overcome after this point was to replace poor quality textures and materials from the BIM tools with better quality ones within UDK. This experience can be broken down to two as; creation and presentation.
In the creation process, I was fascinated by the immersive visuals UDK provided. I was able to observe the design in first person view as soon as I imported the model and I was also able to navigate. This system allowed easy switching among different camera angles within the game engine. This was not where the software reached its limits, but I did. Going beyond this point and actually programming the interface to switch between different camera angles was possible however it required programming skills, which I do not have. Although I was enjoying using the engine, it had just led me to feel unskilled. From this particular experience, I can easily derive that no tool to be used in interactive co-design should make users feel this way, I can only imagine how a citizen for instance would feel when faced with an intimidating interface. Therefore it can be understood that each type of stakeholder needs to have their own interface, which they can interact with in the language they are most comfortable with.

On another aspect, the environment sphere (Figure 15) readily provided by the game engine, immersed me in the environment of the 3D model, which was only amplified by the fact that I could change the time of day to allow for different conditions to be observed. Experiencing firsthand how much an immersive environment can augment the appreciation for the design, I believe an important factor to be included in the proposed tool is the ability to create and host an immersive environment. This immersive experience also allows the objects and surroundings to be more readily transferable to real life objects, which eases the perception process of the 3D surroundings.
This experiment also helped me to understand the value of collaboration in a project where different stakeholders take part. It was the nature of the class, that we had limited time to complete our task. However this may also be the case in real life situations, especially in the interactive co-design space. The specific experience I had regarding this aspect is that because of time limitations, I had to create the environment before seeing either design, and also use the pre-asset trees provided in the UDK library. However when it was time to incorporate the designs with the environment, we saw that these trees, which I used as default, were much more detailed than the actual designs. As can be expected, because of the lack of harmony among the displayed visuals, the presentation did not go well because the attention that needed to be on the design was on the trees. This tells me that the proposed tool needs to have a way of preventing these types of situations via collaboration. This collaboration feature would require the tool to be able to collect different assets pertaining to the
same design from all related stakeholders and give an opportunity for each of these parties to view and adjust them as needed.

Another proposed element of visualization that needs to exist is the interface. This need was made apparent by a few reactions we got from our presentation to the class. Because we did not have a specialized interface for the occasion, we had to just present from the engine itself. Seeing this visually unflattering interface led to confusion among the audience. (Figure 16) When asked if anybody in the audience wanted to give the engine a try, the response was that they would only use such an interface only if it belongs to a game. Game engines, do not make good first impression, when used for something other than developing games is that people can still expect to see a game. Therefore, an interface needs to be included in the proposed tool that looks simple and intuitive while still providing the advanced tools that one needed.

Another very important feature of the proposed tool should be the ability to bring together different media created in any means to ensure the comprehension of all details of the design. For instance in the experiment, as the only visuals we could provide were the 3D models, although they were quite navigable, because we could not provide any images, illustrations, plans, etc. the audience had a hard time grasping the entirety of the designs, making the presentation less informative than it should have been.

This visualization experiment video can be accessed through this link: https://vimeo.com/80889613
Departing from the experiment example above, the features the proposed tool should have can be summarized as:

- Interactive visualization: navigability, immersibility, transferability
- Interactive collaboration: collectivity, comparability, shareability
- Interactive manipulation: modifiability, customizability, convertibility

These elements will be utilized as the main features of the proposed tool and these will be discussed in detail in the next chapter.
4 Features and Aspects of the Interactive Co-design Tool

The fact that the imagined tool presented here is developed with a game engine should not lead to the conclusion that the tool will be a game or even game-like. On the contrary, it will be a tool that embraces all the real-time capabilities game engines can provide while also making the experience for the user much more immersive and engaging. It is also important to note here that game engines allow the creation of such a tool in a cost effective manner, because as long as these tools are used within certain limits, they are free to use. Making tools for use in architectural practice co-design situations, within a given firm, would abide by the rules for free use enforced by the provider of the game engines such UDK. They only require developers to make payments to the company if they make a game, animation or a tool with this engine, and sell it to earn more than some specific amount of money. Since the tool presented in this study would not be commercial merchandise, it does not fall into that category.

This tool to be developed utilizing game engines needs to possess the ability to serve the three aspects of co-design and its enabling features. These features and their roles in the success of each aspect is discussed in detail below with examples. The successful implementation of these features through the three aspects will allow creating the right, effective interactive co-design tool.
4.1. Interactive visualization

The visualization aspect of interactive co-design stands for every facet of the tool that is perceived via the senses of sight and hearing. The features that need to be in place for the visualization to succeed are navigability, immersibility, and transferability.

4.1.1. Navigability

Navigability of the tool is a necessary feature to have, as it allows parties to interact with the tool and the environment or visual being presented. Therefore the tool to be created needs to allow the users to easily and intuitively navigate the 3D space of the design. The tool would also require hardware (e.g. LeapMotion\textsuperscript{42} controller, or OculusRift\textsuperscript{43} as can be seen in Figure 17) and/or interfaces (mouse, keyboard, joystick or newer remote controllers such as Wii) that are easy to use, in order to serve as the transmitter of actions done by the users to the displayed material (visual or text). With the use of such hardware and/or interfaces, the user of the tool need to feel intuitively in charge rather than being overwhelmed by complex controls. This allows the user to concentrate more on the material on display rather than the hardware, which in turn would allow for a more immersive experience.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure17.png}
\caption{On the left: Leap Motion, on the right: Oculus Rift combined with Virtuix Omni}
\end{figure}

\textsuperscript{42} Leap Motion Website: \url{https://www.leapmotion.com/} (Last accessed: December 05, 2013).
\textsuperscript{43} Oculus Rift Website: \url{http://www.oculusvr.com/} (Last accessed: August 09, 2013).
For instance, a technique developed by SHP Leading Design in Cincinnati\textsuperscript{44} invites the stakeholders to observe an environment with a Revit model and Wii Connecter (connected to the software beforehand), which is used to navigate the 3D version of the design. This is achieved by moving the Wii Connecter in order to navigate and observe the design.\textsuperscript{45} While this is an example of interacting with the design via a hand-held interface, with the developing technology of today, it is also possible to achieve this interaction with just using body motions. Two examples of such interfaces are the Oculus Rift and the Virtuix Omni\textsuperscript{46} that can be used together as can also be seen on the right side of Figure 17. By using these two in unison, the user is able to perceive the environment in 3D via the Oculus Rift goggles he/she puts on and the Virtuix Omni allows the walking action by the user to be captured and transferred to the environment, allowing the user to navigate in the 3D space.\textsuperscript{47} Interfaces such as these are clearly more successful than their rivals as they can be used in harmony with game engines, allowing the technology to be transferable to the daily life and the daily user. The best sign of the ease of coupling such interfaces with game engines is that developers of game engines and the hardware developers produce development kits in collaboration for programmers that would like to use that hardware with the game engines.\textsuperscript{48}

Navigability is not only about letting the user navigate or explore such a 3D environment. It also requires proper direction to be given to the user with an integrated system in a way that maintains

\textsuperscript{45} Ibid.
\textsuperscript{46} Virtuix Omni Website: \url{http://www.virtuix.com/} (Last accessed: April 25, 2014).
\textsuperscript{47} A demonstration video for how the OculusRift and Virtuix Omni works together can be reached at: \url{http://www.virtuix.com/videos/#video_ZC2Tvha9n4} (Last accessed: October 10, 2013).
the flow of exploration. This integrated direction system can be thought of as a basic tutorial on how to navigate and use the tool, delivering the necessary information through, for instance, informative balloons either floating in the foreground or as signs attached to elements of the design. This would allow for a more hands-on learning rather than receiving a briefing in speech or writing. Navigability also entails the ability to switch between features and basic design elements such as construction, conceptual, circulation, etc. or the ability to control those menus with gestures through the interface.

Although the interactive co-design process does not imply a hierarchical process (Figure 11), it is important to note at this point that navigation is the moment the whole process and its features are triggered. This can be rationalized by thinking that it would be impossible to have any observations, or thoughts for that matter, without starting to navigate the displayed material.

4.1.2. Immersibility

Immersibility concerns the extent to which users can perceive the space as if they were present in the environment they are navigating. This should be achieved by focusing on the more readily understandable aspects of the design such as the 3D environment, rather than keeping the focus on more complex displays such as plans of the design. Although the use of both is necessary, the attention must be on the more visual aspects. While the designer can share his/her design with any means (2D or 3D) necessary with ease, users should be immersed in the environment, enabling them to feel comfortable with the tool and the environment. Immersibility can be achieved with the use of body as camera, environment sphere, animated 3D objects and environment, ambient sounds, and the harmony of these individual elements.
The first thought of creating an immersive environment was achieved by the “Panorama Mesdag” (Figure 18) painted by Hendrik Willem Mesdag in 1880. The environment in the painting could be observed almost as if the people were immersed in it.

![Figure 18 - Panorama Mesdag by Hendrik Willem Mesdag (1880)](image)

These elements allow the creation of a more transferable, immersive and modifiable environment, including when used with a physics engine when necessary (this capability of game engines will be discussed in detail when talking about transferability and modifiability).

Let’s take a look at an example where an older representation of the same environment is compared to a newer one; and see how 3D environments can contribute to the improvement of the immersibility level.

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When the environment that is seen in Figure 19 was created, in 1993, the technology only allowed the use of 4 images in the 4 main directions to give the sense of 3D. Each image would be triggered to be loaded by pointing and clicking in that direction. Whereas Figure 20 takes us to year 2000, and now we are actually navigating in the immersive 3D environment.

4.1.3. Transferability

Feeling comfortable with what one sees in a visual representation is achieved by including elements that are in harmony with the concept of the design, the rest of the design elements, and the real life correspondence. When this is successful, it can be thought that what the user experiences is clear of any shocks, confusions, or frustrations. While creating a surprise can be the goal of the designer or researcher, this should be planned and not be realized in a negative way. Throwing unknown, unrecognizable objects at the users without providing any information or any rationalization as to what these are and what their purpose is should be out of the question.

52 Sanders and Westerlund, “Experiencing, Exploring and Experimenting in and with Co-Design Spaces.”, 301.
Transferability does not only apply for the elements of the design, it also pertains to the hardware and interface that are being used to navigate. For instance, what things refer to within the hardware or the interface being used is an important issue\textsuperscript{53} (e.g., what happens when I wave my hand?). Seeing the representation of the actions taken by the user on screen allows for this to be transferable. This is another element that should be included in the tutorial and should be integrated throughout the tool.

As can be seen in the above discussion, the visualization aspect seeks to create a wholesome environment to maximize the immersive experience by the user. Making use of game engines gets us closest to this, which allows us to create that immersive environment while still allowing interaction rather than being a still rendering or a predetermined animation. This feature also allows the visuals to be transferable with ease.\textsuperscript{54} This is one of the many reasons game engines have been chosen as the medium to develop the tool proposed for interactive co-design in this study.

Based on the discussion above regarding the three features of visualization, it can be said that visualization is the enabler of a successful interactive co-design process. Without proper visualization, collaboration, and manipulation can still be done however the process and the results would be suspect.

Creating the tool according to the features described above provides the tool with good visualization. However, without someone to experience this with its entirety, no value can be reaped from the

\textsuperscript{53} Google Android Team talks about the value of being able to interact with what you see in real life also on the screen (what you see vs. what you interact with needs to be similar to be intuitive) https://developers.google.com/live/shows/598259567 (Last accessed: August 30, 2013).

\textsuperscript{54} An example of how immersive graphics can be achieved with game engines: Abdeen Palace with UDK http://www.youtube.com/watch?v=7_h0UnUdlHB (Last accessed: October 12, 2013).
interactive co-design process. Therefore, after getting the tool ready in terms of visualization, it is important to make sure the tool also harbors collaboration, which is the way parties will experience the materials and share with each other their thoughts and actions.

4.2. Interactive collaboration

The collaboration aspect concerns the deliberate communication, clear idea generation, and interactive brainstorming among the designers, researchers, and users. The features that make collaboration as fruitful as it can be are collectivity, comparability, and shareability.

4.2.1. Collectivity

Ensuring collectivity requires the tool to speak to all possible parties including the users, researchers, and designers. This can be achieved by housing various features and capabilities within the tool to allow all parties to use it according to their own needs.

For instance when one logs into the tool, they should only be seeing what they will be using according to their role in the project. The home screens and the dashboards available to each role will be unique to that role. The user is greeted with a welcome message that talks briefly about the study, followed by a tutorial that will take them through the basics of navigation within the tool. Designers need to be in charge of the visual facets and the interface the user sees, may need to view user data, or review/change information regarding the model, therefore they should have control over these elements. Being the method’s facilitator, the researcher needs to see and change the welcome screen for users, create and save documentation regarding the process, view and run basic analyses on user data, and have the ability to export these to 3rd party software (this is entirely about
the convertibility feature set forth by the manipulation aspect, as will be discussed below). This approach provides relevant uses to each party and therefore becomes a natural part of the process and gives the tool its collective nature.

As can be seen in the above discussion, the use of this tool can generate many data points with the comments of users, different types of annotations, demographic information, and also the visuals provided by the designer and so on. Mountains of data are difficult to assess and visualize, yet they still can be useful. Therefore, there is a need to be able to capture this value with ease. The tool needs to have the ability to superpose or juxtapose any type of data as necessary. For instance, looking at the different states of design can prove to be useful.

Collectivity allows for the existence of the following two features of collaboration: comparability and shareability, as will be discussed below.

4.2.2. Comparability

Keeping an account of the interactive co-design process (by saving these in the database), as co-design also proposes, can prove to be important. This approach allows for all parties to be able to keep track of how the design has evolved over the course of the interactive co-design process. Furthermore, other than the two endpoints (beginning and ending) of the design, there might be a need to compare other points. These two points to be compared can be two different points in time, or viewpoints of two different users. The biggest contribution of comparability to the interactive co-design is its ability to display the similarities and differences of the design ideas of different parties. These types of comparisons would allow the easy identification of differences of opinion and therefore give the parties a chance to work on these points without it becoming an impasse.
In addition to being able to save and load from a saved point, it is important that the tool allows an alternate path to be created by resuming from this loaded point. The most important thing here is that the alternate path does not overwrite the old path but simply creates an alternative route. After setting up the tool to gather all these different viewpoints, it would make perfect sense that these should be saved so that any of them can be revisited at any time. For instance, in a game called Prometheus (Figure 21), the player can do an action and then go back to time zero to observe him doing the action in the first version, and then do another action. Seeing your previous selves and actions allows you to avoid mistakes and come up with new ideas by keeping track of what has been tried and which of these were successful and which ones have failed.55

![Figure 20 – Prometheus Game: observing previous actions](image)

The ability to create simultaneous paths allows different groups to create different alternative solutions and then these can be compared with each other. It should not be forgotten that, as

55 Developed by Rachel Cordone, Prometheus Game. The video can be reached at: [http://www.youtube.com/watch?v=2n1NLwcEga8](http://www.youtube.com/watch?v=2n1NLwcEga8), (Last accessed: June 10, 2013).
myopic as developing a large-scale project according to one person’s point of view, reducing all the different viewpoints gathered to a general average can be just as ineffective. Alternatively, the differences of these groups should be embraced. This would be an important outcome for interactive co-design process.

Identifying these different groups is achieved by the collectivity feature. As it is possible to save users’ roles with the tool, it is also possible to use these roles to group them together. Therefore if the tool lacks the collectivity feature, comparability would not be possible.

4.2.3. Shareability

One other critical feature of interactive co-design is the ease of sharing among different groups. For instance, a comment added by any user should be visible to any party within the co-design space. Similar threads should be grouped under common headings, which again could be accessed by any party. An automatic text analysis should be running in the background, allowing tags to be automatically created according to the words used. Input from this would then create tag clouds that would represent what are the most common comments made about the specific area or object. These tag clouds would provide the parties with the ease of surfing through the tags to see what comments have been made regarding a certain feature.

These comments should also allow participants to use various means to express what they want to, including writing, drawing, capturing voice and/or video, referencing image or video from the web, uploading images or videos from the users’ own devices, and scanning documents. Providing this variety is important for making the tool as encouraging to use as possible. This type of ease of sharing nurtures collaboration as it recognizes the variety of people and the different comfort zones
they have. Instead of asking them to use one way of sharing thoughts, this way allows the users to feel appreciated, valued, and welcome.

While these three features nurture a successful collaboration among parties, collaboration serves as the key point of interactive co-design, as it gives way to recognizing the user as a critical part of the process and allows for the thought and information exchange among parties.

Although collaboration allows for the users to share their thoughts in various forms, sometimes these means of expressing comments may not be enough. At this point, having the option to actually make changes themselves can be satisfying and also more informative and clearer, especially in situations when the change to be made is hard to be explained in any other format. This is why the last but not the least aspect to be discussed is manipulation.

4.3. Interactive manipulation

This feature is mostly useful in getting expert opinions to contribute to the interactive co-design process. This should not mean that experts are the only ones who can use this, but the more experienced a user is with such visualization means, the more proper the changes they make will look. Referring back to the collectivity and comparability features, any party can reach these manipulations by the help of the interface and edit it to create alternatives, again creating new versions by not overwriting. To be able to grasp the breadth of manipulations that can be done, each object or design element can be modified, customized, or converted. Different representations of these objects and elements should also enjoy the ease of switching back and forth and also superposing in order to truly capture the different viewpoints and different combinations.
4.3.1. Modifiability

Modifying objects/elements entails moving, scaling, and rotating in order to either reach the desired look or to observe the objects or elements in question more thoroughly. While participants can use the modification feature to change the size, scale, and location of any object or element, they may also combine this feature with shareability by adding their annotations in the comment type of their choice (written, voice recording, etc.). This can allow parties to make modifications that convey their thoughts more clearly. However useful these functions might be, the parties should also have the ability to observe the objects or elements from a more out-of-the-body experience in the tool with the use of different camera angles. This can help with the modification process as it will not force the party to move around the object in order to see different views of it, but rather have the ability to look at it from different viewpoints. This actually triggers a whole new level of visualization that is built in to the tool. While changing camera angles, the user should also have the option to return to the default at any time to avoid wandering around trying to find where the object of interest is.

As game engines seek to approach life-like experiences, knowing what these capabilities are and using them to suit the needs of the tool and knowing when to not include them is important. For instance, a demonstration using the Unity game engine along with Leap Motion was prepared. In this demonstration, 3D objects placed in the Unity game engine can be moved with hand gestures with the use of Leap Motion. Due to the physics engine in play within Unity\textsuperscript{56}, the objects fall and tip

\textsuperscript{56} Unity with Leap Motion Demonstration: http://www.youtube.com/watch?v=seEtw1FM6G0 (Last accessed: September 15, 2013).
over according to gravity. (Also in UDK\textsuperscript{57}) In case this is not a wanted feature, gravity can be toggled off in the game engine, in order not to frustrate users. As can be observed in the video game called Surgeon Simulator 2013,\textsuperscript{58} delicate handy work can be hard to achieve with the gravity laws in action, even if you are controlling the interface via a keyboard.

4.3.2. Customizability

The need for customization may arise from various participants expressing thoughts about textures, colors, materials, and shapes in a more self-explanatory way. As was the case in shareability, notes can be taken and also textures, colors, shapes, and images can be brought into the design element to create a collage in order to better demonstrate what kind of a change is recommended by the user or groups. The interfaces provided with the tool should accommodate all customization options that may be needed.

An example can be given of the customizability of the Unity game engine as a demonstration by Juan Camilo Alcaraz.\textsuperscript{59} In the demonstration, an environment like a studio apartment was created and the user is given the ability to move within the apartment with the use of a keyboard, and change the color and texture of objects and walls in the space with the use of a mouse (Figure 22).

\textsuperscript{57} UDK with Leap Motion Demonstration: http://www.youtube.com/watch?v=vYFqr2weXuA (Last accessed: October 1, 2013).
4.3.3. Convertibility

This is the only feature that excludes the users. Convertibility is necessary for designers and researchers to be able to import and export different types of files into and out of the tool. This is basically necessary because not all the software platforms that are used by designers and researchers can be integrated into the tool, since this would exhaust all the resources of the machine the tool runs on. Additionally, there is no need to incorporate them into the tool, as the interactive co-design space is neither where the designer does the creation of the design nor the researcher conducts complex analyses.

This is also the only feature where the tool allows designers to import/export their design with a specific workflow using BIM tools. There is a specific workflow that needs to be followed in order to convert the output of BIM tools into an input of game engines.

This workflow consists of five steps:
1) Open your 3D model in the software or BIM tool you used (Rhino, Revit, ArchiCAD etc.)

2) Save your assets into different OBJ files (doors, windows, railings, roads, walls, roofs, etc.)

3) Open each OBJ file in Maya one by one, explode the objects and delete intersecting vertices, then export as 3DS.

4) Open the 3DS file in 3DsMAX, then save as FBX file.

5) Upload FBX into the game engine.

This workflow is demonstrated online at this link: http://www.hamdimortan.com/pipeline/
Discussion and Conclusions

The three aspects of the interactive co-design process and the features of each of these aspects as identified, defined, and discussed in this study provides the fundamentals that should be taken as the basis in the process of creating interactive co-design process tools using game engines.

One could possibly argue that since the tool proposed in this study is yet to be developed, the effectiveness of it cannot be argued concretely. However, I believe the approach taken in this study, the insights that the proposed tool and its aspects was built upon, provides a rich context of the tools that are discussed to be good alternatives for serving as effective interactive co-design tools. Additionally, this study is positioned to pose as a conceptual work that looks at the limitations of conventional tools of co-design and innovates a new way of managing the interactive co-design space.

One also cannot dismiss the fact that convertibility feature of manipulation is the weakest point of game engines as well as BIM tools. The only common file type among these tools is FBX files. The conversion of other file formats into FBX is still not without its flaws. Therefore a crucial issue is that there is only one link between BIM tools and game engines and it is a weak one. This however is in no way a weakness of this study, because although this is the current reality of these two tools,
in the foreseeable future, it is very probable that such issues will be resolved and the applicability of this conceptual study will be increased.

Keeping the previous point in mind, the contribution of this study to the literature lies in its attempt to bridge the gap between stakeholders in the co-design process, and a thorough assessment of relevant tools (both existing and possible) in a holistic manner.

In conclusion, this study provides the literature, the practices and the criteria for an effective process tool that can assist in the interactive co-design space.
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