PARAMETRIC BIM AUTOMATION

by

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ABSTRACT

JASHWANTH LAKSHMANAN. Parametric BIM Automation. (Under the direction of PROF. ERIC SAUDA)

How can parametric design process be used in design and apply it to spatial planning to buildings with a set constraint and automate modelling process is the research question this project would prove to answer.

In today's highly advanced world where technology and automation has become a big part of our lives and many different fields of work, we architects have been slow to adopt and adapt this into our field.

'We may have come away from drafting each and every line on paper to a digital world but about 40 percent of architecture firms still draft each line in Auto CAD. Also, the process of design from clients to architects and engineers to contractors is not very well coordinated and takes too long, there always seems to be a break or leak in the information being transferred from one major party to another. Although BIM has brought about significant changes and improvements the process of modelling and designing can use an upgrade that can boost the process. This upgrade could possibly be realised by using parametric tools that can alter entire designs in a matter of minutes very efficiently.

So through this research I wanted to prove and experiment that most of the mun-dane tasks while modelling a building can be automated and this automation could be extended to automate entire projects. And possibly also test its limitation i.e., how far can we automate the different types of projects and why.

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LIST OF ABBREVIATIONS

AI Artificial Intelligence.

BIM Building Information Modelling.

CAD Computer Aided Drafting.

CD Construction Document.

DD Design Development.

SD Schematic Design.

UI User Interface.

CHAPTER 1: INTRODUCTION

"Every good design has to be based off of geometric patterns and set constraints."-Vitruvius (who was loosely termed as the first architect), which is very close to what "Logic Of Architecture" has to say on computational design and shape grammar. Mitchell first considers how buildings may be described in words and shows how such descriptions may be formalized by the notation of first order predicate calculus. This leads to the idea of a critical language for speaking about the qualities of buildings. This language and grammar could be used as a set of rules and constraints for the model automation process.

Similarly if we were to deconstruct buildings and spaces into a language or a set of algebraic expressions for our computers to understand, we could possibly just "ask" the computer for a building based on a set of "parameters" like type/size/height etc., and the computer would use the code that we had defined previously as the standard expression or language for that particular set of parameters or use those parameters to replace the variables in the equation to arrive at a solution that answers all the parameters we've set and provides us with a BIM model.

Autodesk once advertised a tool which can model entire houses with just one click for a perpetual license fee of 25,000 dollars. This was an April fools trick where the link transferred the user to Wikipedia's April fools page. But today we may be able to realise this trick into reality with Parametric tools like grasshopper and dynamo. The process might take more than one click but with considerable amount of automation it should be able to produce an entire building model. Where we can set the base constraints and highlight the main variables we would want to control or the ones that are prone to constant change we could create 3d parametric models. In addition to

visualising the future hotel building with these tools we could potentially use the same model or the information from this conceptual model into the practice as well. I.e., the computer generated model could directly be used in an architecture/engineering firm rather than having to sit and model each wall every time there is a change in design.

The idea behind integrating computers into the architectural field is to not replace architects but make them more efficient designers by letting the machine take over mundane repetitive tasks and allow architects to concentrate more on the âDesignâ aspect of the project. Lots of research has been done trying to integrate these tools in the design and modelling process of many different project types but what most of these design automation systems seem to lack is the ability to transfer the information into construction documents but rather just serves as information to create another model for the construction document set. One particular project design type that is suitable to test the Generative Parametric design process would be the hotels. Since most hotels have a pre prescribed program and space requirement, which can be translated or programmed as constraints that can be used to generate multiple model solutions and options to provide us with the best possible mathematical solution.

The longest and the hardest part of any architectural hotel design project is at the initial stages, where architects need to discuss/negotiate with the clients of the program and decide on the numbers like the total cost, the different types of guest rooms, the percentage of the different types of guest rooms to use, the total number of rooms, the number of floors, plot area and so onâŠ getting these numbers is not easy and most often the architects model the entire building and find themselves redesigning and hence create another model from scratch since the numbers don’t add up or the client has decided to change the number of rooms cause the budget seems to be too high. So it certainly isn’t easy changing those numbers once we begin modelling the hotel in BIM.

The main idea of this thesis is to create a tool that has preset parameters and constraints of a hotel and leave key variables to be changed and manipulated by the designer/owner to go through many different models in a much lesser time frame and obtain the most optimised design and further develop it into the DD and later CD phases. To create a tool with a user UI that can take different inputs like site, program,program percentages, cost and create a variety of options based off of the above mentioned variables while providing outputs like profit margin, visual model in addition to the different design options by comparing cost with profit to get the most optimised result with the least cost and maximum profit.

CHAPTER 2: LITERATURE REVIEW

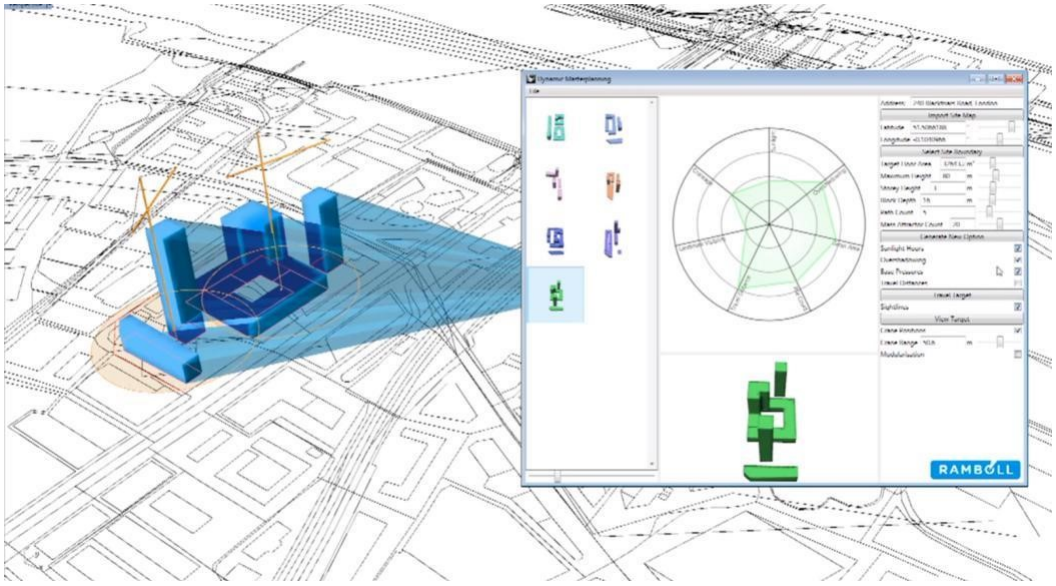
2.1 Ramboll SiteSolve And High Rise Explorer

Overview : Ramboll is a UK based construction company that uses heavy computational methods in their design and construction. SiteSolve is an invaluable tool for landowners and property professionals looking for ways to unlock the potential of available land, increase cost certainty and return on investment. SiteSolve fully explores and evaluates building development options at the early-stages of decision making, maximising site potential and minimising technical risks. What ramboll tries to accomplish is to try and bring all the construction sectors together as one in the very beginning to calculate all the potential errors/hazards and loses, very early in the game to avoid/counter those errors and possibly plan for a better design. The tool even shows us how traffic patterns and crane placement to place the precast blocks for the building design.

Pros : This has a very good UI for the clients to manipulate easily and real time data as the model is being changed so the client can make informed decisions before even deciding to invest in such a project and if they did what kind of structure would be best.

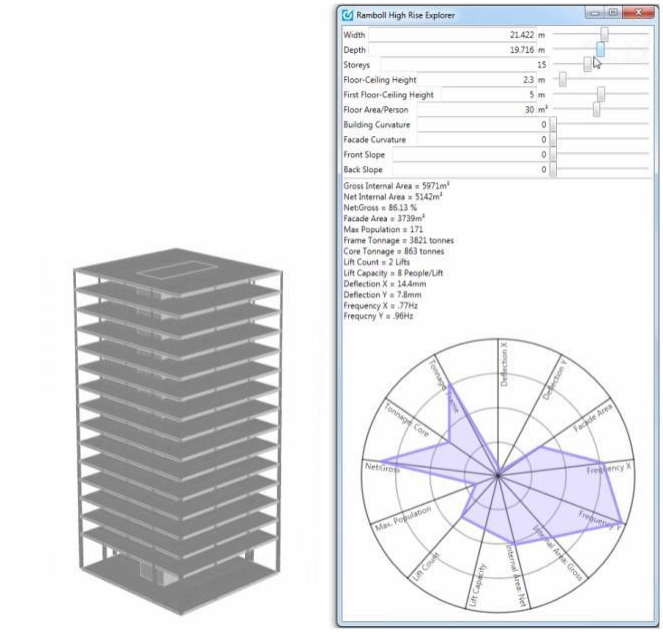
Cons : Although theses studies are amazing and help to a great extent in making crucial decisions in the early stages of a building, it does not address any kind of building program so this would not prove to be very useful after the initial run for any building which is not a high rise. Also these would only prove to be helpful for preliminary studies and hence the designers would have to model the entire structure from scratch in a BIM software to be able to generate construction drawings. Which this thesis is trying to combine into one process where we can obtain the preliminary

studies and create a BIM model as well.



(a) Grasshopper using Galapagos to find optimal crane positions

Figure 2.1: Ramboll's Site solver tool in action



(a) Ramboll's High Rise Explorer

Figure 2.2: Ramboll's High Rise Explorer

2.2 Generative Urban Design

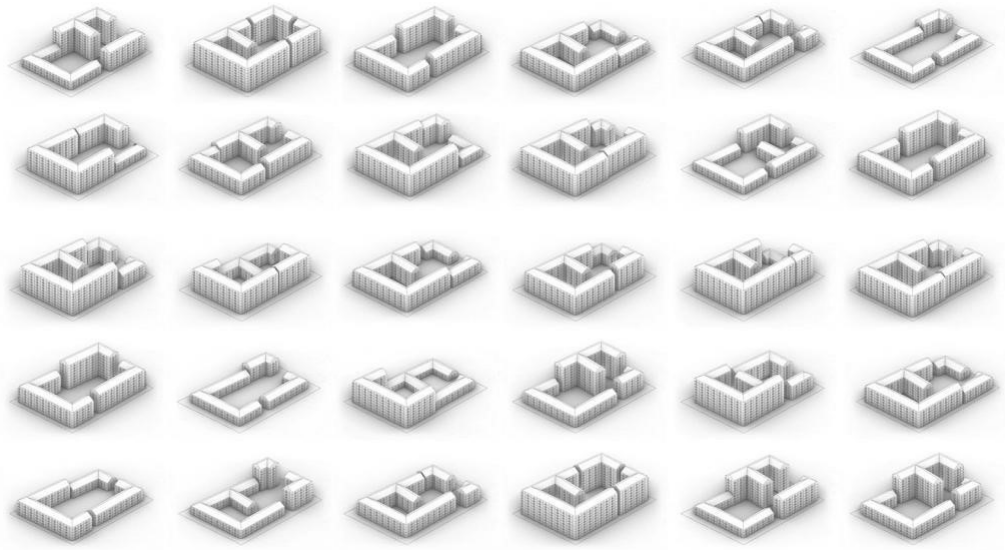
Overview : Andre agi has developed multiple algorithms and scripts to automate different office layouts (feasibility checker) and even different layouts on an urban scale(Adaptive urban planning based on different circulation patterns). He used multiple variables and created a dashboard for data visualisation that outputs real time data output of the different variations of the model. He uses a whole set of rules and constraints in grasshopper that are linked to variables such as traffic routes and road patterns. So he generates a whole bunch of variations or urban design designs based on the routes and occupancy.

Pros : His project has a very good UI for the common client to be able to use hi complicated tool and also has multiple dashboard options to see the output in real time. His scripts are both generative and parametric in nature making it a very powerful tool.

Cons : Although this is a very interactive tool that is very accurate and user friendly it is still conceptual and could âhelpâ the designers make better decisions while designing but does not generate a model with program in it neither can it be used for construction.

(a) Andreas Agi Urban Planner

Figure 2.3: Layout evolves as the road path keep changing



(a) Andreas Agi Residence Planner

Figure 2.4: Layout evolves as the requirements keep changing

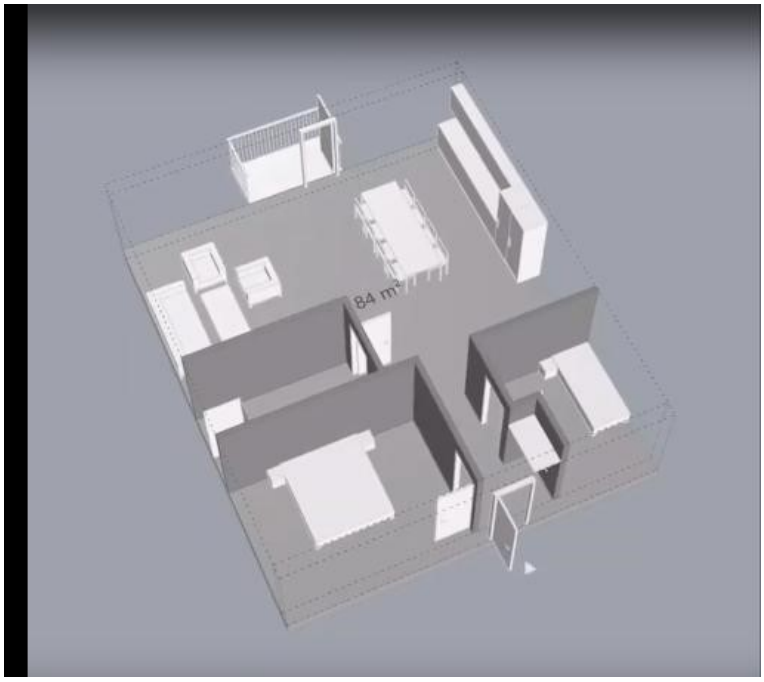
2.3 Finch 3D - The Adaptive Plan

Overview : Jesper walgren uses grasshopper to create the adaptive plan where the furniture and the furniture layout change as the floor footprint changes. This

could prove to be very useful in a parametric building where there could be multiple sized rooms and the furniture layout could adapt itself to the room size. They used grasshopper to program this and used space constraints to have furniture appear and disappear based on the size of the said room. We can see that as the length increases new room types appear with new furniture configuration.

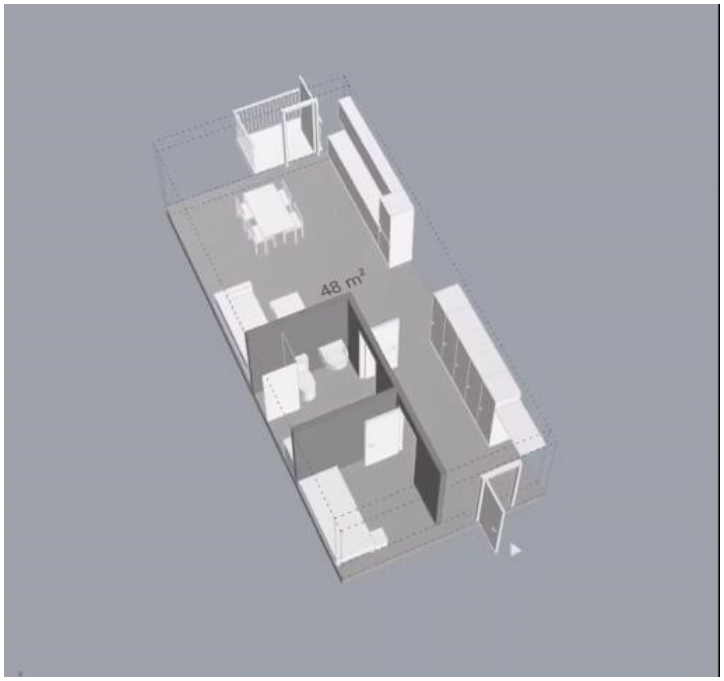
Pros : It is very impressive to see how the 3d furniture layout changes as the area of the floor plan changes i.e., the script even adds and takes away furniture component as the size increases and decreases.

Cons: Although the animation is very interesting to see it is still unclear how we would use it in a project i.e., there is no clear end user UI to make the idea work in ANY design and this is very specific and limited only to the furniture layout in a room but with no optimisation. Again this tool has been developed in grasshopper which is a very useful parametric design software but does not provide us with the necessary information to create construction drawings.



(a) Finch 3d Plugin

Figure 2.5: Layout evolves as the space keeps changing



(a) Finch 3d Plugin

Figure 2.6: Layout evolves as the requirements keep changing

2.4 Parametric Siemens Building with Generative Design

Overview : This is a Masterâs thesis of a civil engineering student Jacqueline Rohrmann in germany. This video was posted on 09/09/2019 so itâs very new and the thesis hasnât been published yet. She had assigned parameters to a bunch of rules for the office building and ran it through refinery (evolutionary software) to get the most favorable design output by prioritising/favoring one variable/output over the other or by trying to maximise one of the outputs. She has used the constraints in the spaces of a siemens plan that are fairly rectangular and linear, she used occupancy as one of the constraints that need to be maximised by using the evolutionary solver. So now the design is maintained but only the spaces change in length or breadth and remain within its boundaries. By maximising the occupancy and limiting the cost/boundary.

Pros : She actually parameterised the entire building along with itâs program into

one dynamo graph and then ran the evolutionary software to get the best set of design options for the designers to pick and choose from, which is very close to what I am trying to achieve.

Cons : Although she had a parametric building and used the evolutionary software,The program is very basic (only 3 different types) and it is only conceptual. Meaning the architect has to choose the best option and still create a BIM model from scratch. This also lacks a UI for anyone who is not proficient with dynamo to use.

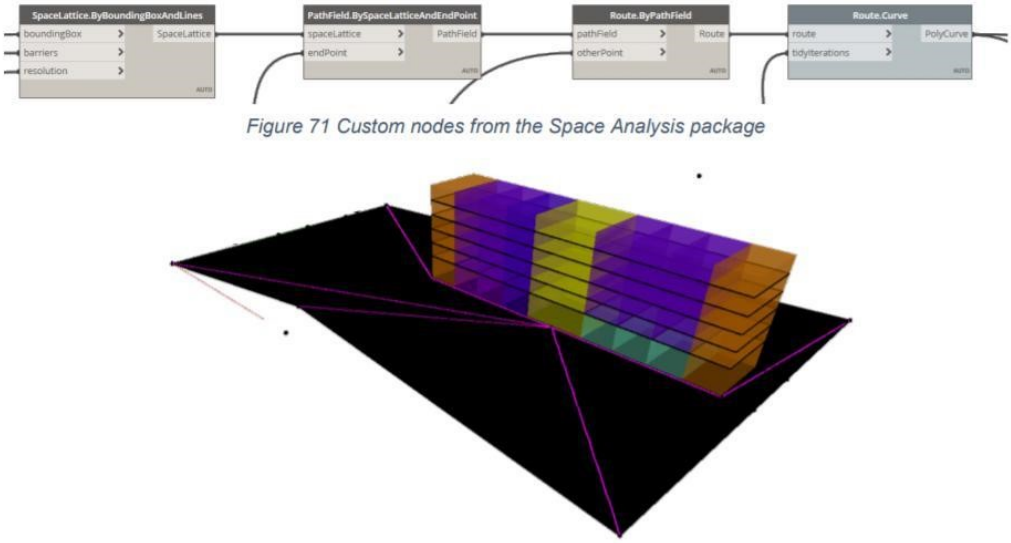


Figure 71 Custom nodes from the Space Analysis package

(a) Using Dynamo to find the most optimum organisation

Figure 2.7: Layout evolves as the requirements keep changing

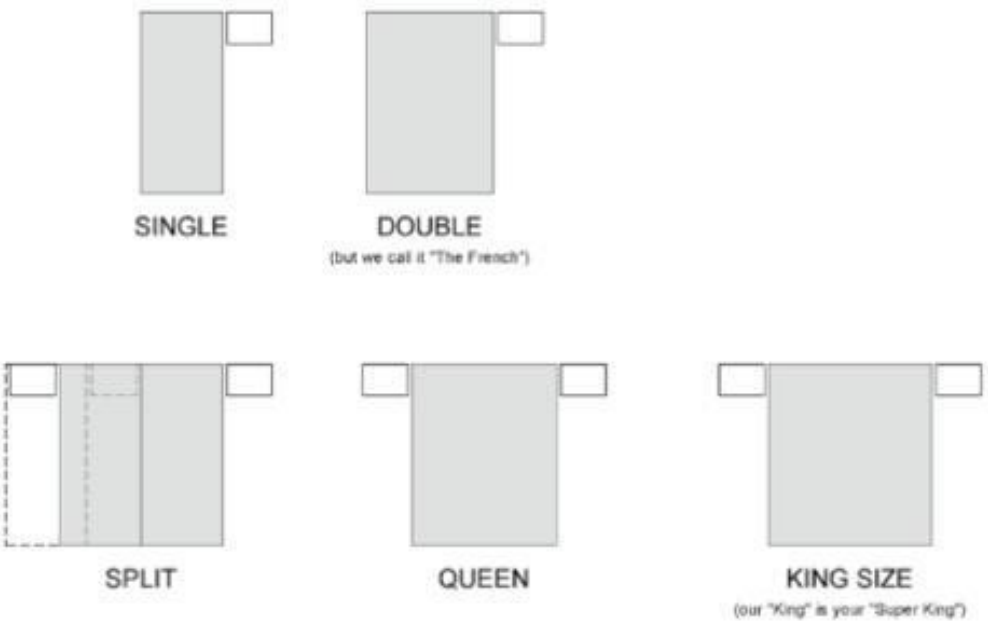
2.5 BIM for Hotels: Revit Automation for Rule-Based Spaces

Overview : In this lecture from autodesk university they talk about using dynamo and flux to get input from clients and automate the standard elements in a hotel project like the furniture in the room and the shower stalls in the bathrooms etc., This was a workflow to create a library of all that is constant for a specific project like for example they show us how we can automate all the toilet accessories for a specific type of guest room. Since a hotel has all its furniture and accessories in prescribed

spaces, so we know where everything is going to be at. And by using dynamo we can preset all these accessories to place themselves in the right positions.

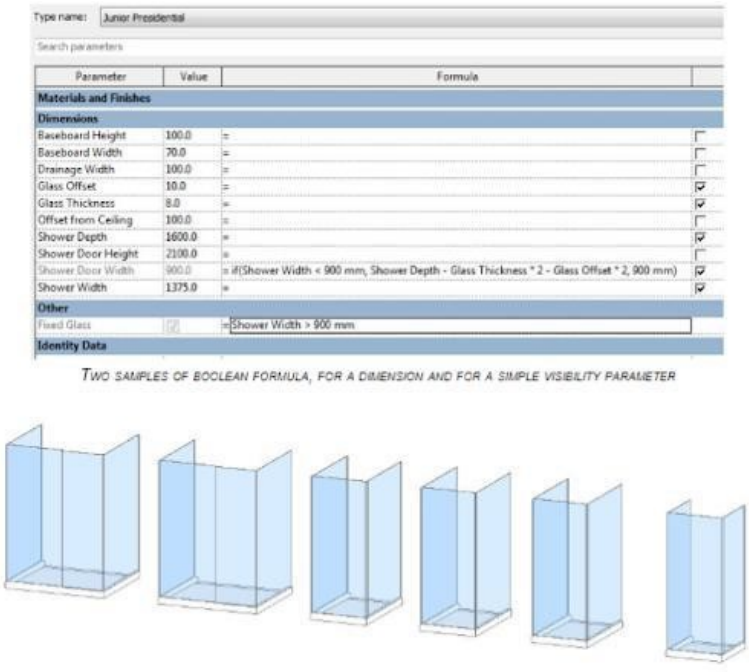
Pros : The main advantage of this lecture is that it is simple, straightforward and relatively easy to perform as hotel configurations barely change so automation would be fairly easy like automatically placing furniture inside a room etc.,

Cons : Although they roughly have the same idea as my research project, this project is only a fragment of what could be achieved if we were to incorporate larger parts of a building simultaneously in different variations by using generative design. Here they have created many different dynamo graphs to automate certain PARTS of the entire building, which is quite simple as one part of automation does not need to communicate with the next part of the building design i.e., when parameters are changed only a part of the building would react to it and the rest would not. Thus creating a model that is either broken or different in different parts of the building. This is just a showcase of a tool automating some of the laborious work while modelling a building.



(a) Using Dynamo to automate bedroom furniture

Figure 2.8: Layout changes as bedroom type changes

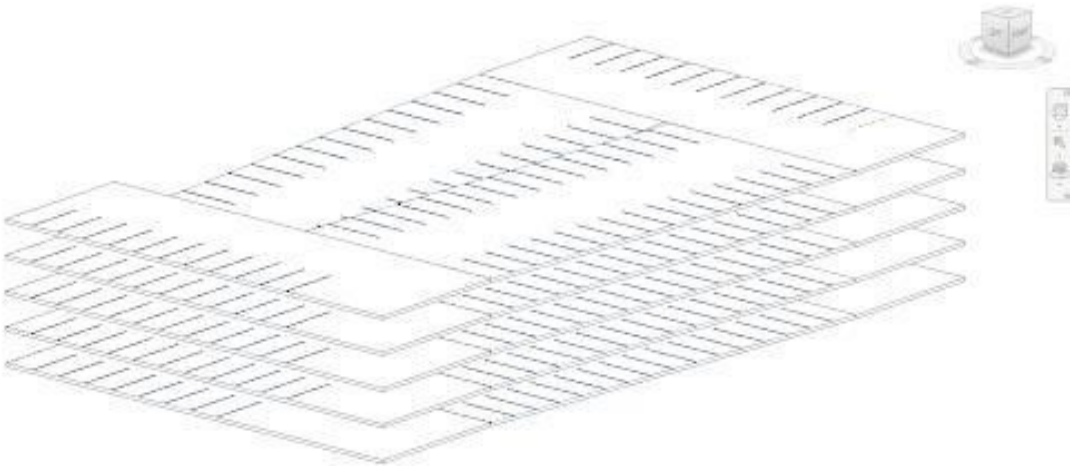


TWO SAMPLES OF BOOLEAN FORMULA, FOR A DIMENSION AND FOR A SIMPLE VISIBILITY PARAMETER

(a) Using Dynamo to automate toilet accessories

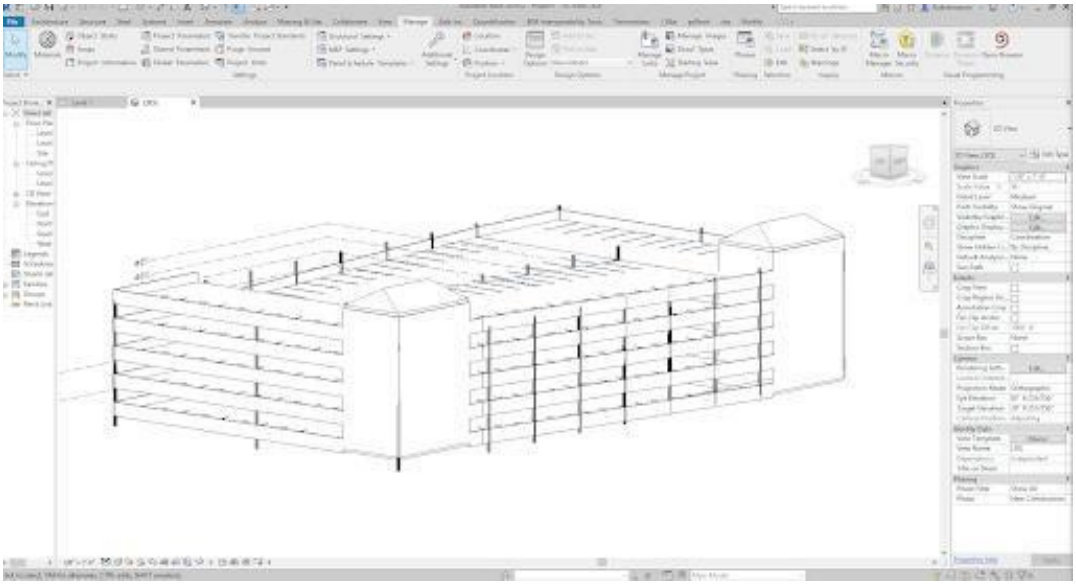
Figure 2.9: Layout changes as bedroom type changes

CHAPTER 3: PRELIMINARY RESEARCH SPRING 2019



(a) Using Dynamo to automate a parking deck given a set of parameters

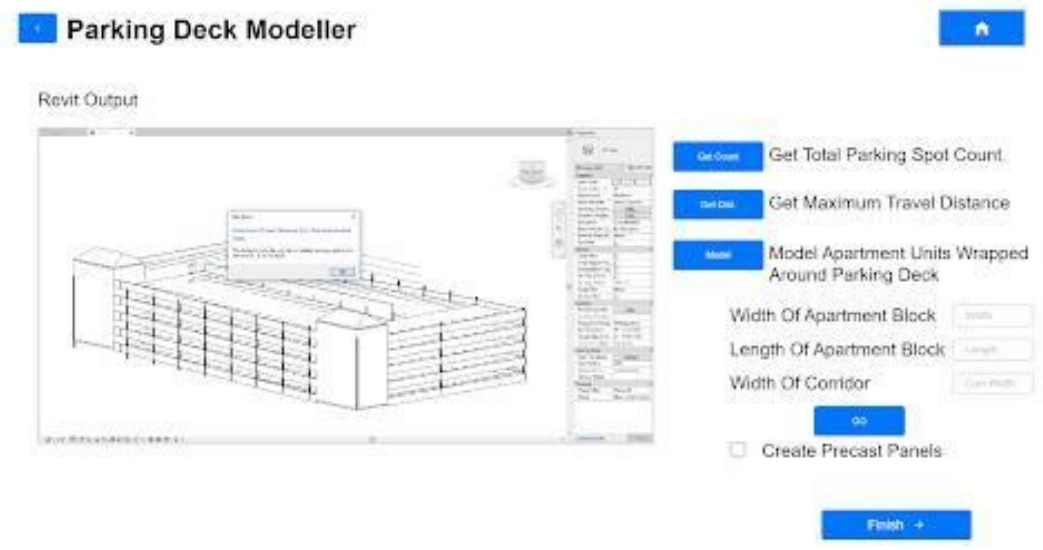
Figure 3.1: Parking deck changes size and height as required



(a) Using Dynamo to automate a complete parking deck

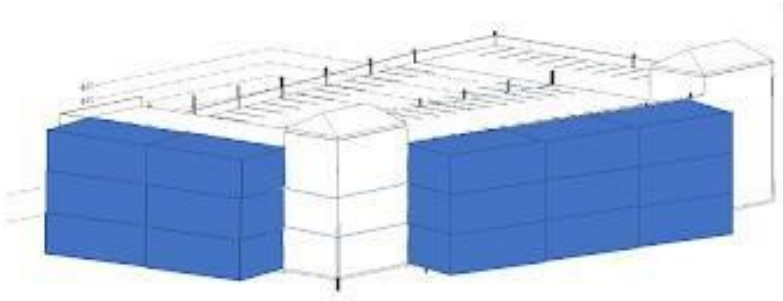
Figure 3.2: Completed parking deck with wall

As a preliminary research test for the thesis with automation of design, I started off with a very simple design i.e., a parking deck. Since a parking deck has little to no program in design there is not much variation in the design of the parking deck from one to another. So it only needs to satisfy the standards and code set by the state, which is pre configured in the code and users are allowed to use this tool to create parking decks that suit their needs. A user interface asking the users to enter the values for different parts of the parking deck which is entirely parametric. Like the height of the building or the number of floors etc can be customised to suit the needs of the user. The user can later decide to add in apartments on the border of the parking deck itself. And like everything parametric the user is able to specify the width and length of the apartment units. Fig 3.1 shows the floor system along with the parking spots for the provided site, showing the maximum number of parking spots and the general design. While Fig.3.2 shows the entire parking deck model complete with walls, floors,stair towers, levels etc., after successfully running the parking deck tool.



(a) Using Dynamo to automate a complete parking deck

Figure 3.3: Parking deck tool's User Interface



(a) Using Dynamo to automate a complete parking deck with apartment units

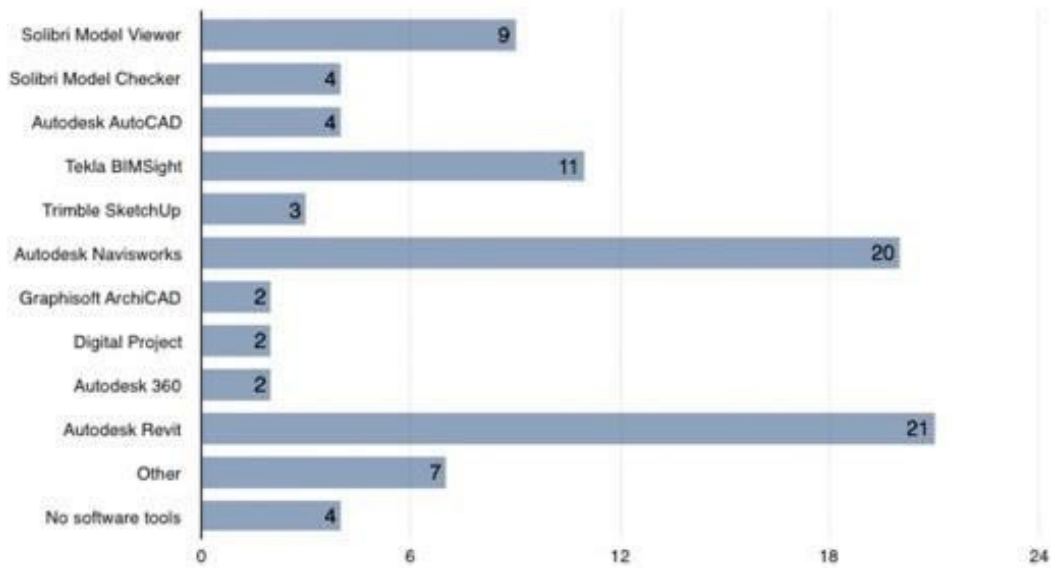
Figure 3.4: Parking deck tool with apartment units

3.1 Why Revit?

Many of the case studies that have been mentioned above primarily use grasshopper and tools other than revit and have accomplished fairly more than what i strive to achieve in the conceptual area.

Parametric tools like grasshopper in rhino are able to bend any shape and take any form that can be conceived by the human mind, but in revit to create a form a whole set of constraints need to be set. Even to create a rectangular form revit demands an exorbitant amount of data and hence we do not find the flexibility many designers would prefer.

But Revit mimics real world outcomes and hence can be directly used to create construction documents, track a live project and increase communication between the sectors of the construction industry by tieing them all together under one giant roof of BIM.



(a) Revit Statistics

Figure 3.5: Revit Statistics

In a free comments section, some of them mention the importance of display devices, e.g.:

For having a common visual support during discussions

For rapidly understanding the issue being discussed

For the capability to interact with datasets (3D visualizations, linked data etc.),

For the immersive dimension, enabling to better involve the participants in the discussion, As well as for direct annotation and collaborative tracking of decisions.

Finally, the respondents were asked about the BIM software systems they use during the co-located meetings. Software enabling the direct visualization of building mod-els are referred here. The above image shows that most of the respondents to this questionnaire are using Navisworks (20 answers) and/or Revit (21 answers) systems from Autodesk. Tekla BIMsight (11 answers) and Solibri Model Viewer (9 answers) are also well used. 4 respondents out of the 39 mentioned not using any software system.

3.2 Methodology

The semester began with the search of finding ways to make an architects life easier by creating tools and add ins that automate the mundane tasks that need to be performed while creating drawings that go toward permit.

So I started this pursuit toward automation by researching and making notes of all the mundane tasks that are to be performed in the everyday life of an architect. As I started making a list of the task and standards that could potentially be pre configured in a script, I realised that I could potentially write a script that could automate and design an entire building controlled by a set of parameters that would channel the design requirements.

So as a preliminary research of automation in design and build I decided to test out parking decks. Since a parking deck has a very simple and well defined program, all that was needed to create the algebraic expressions for the programming was the stateâs minimum code requirement and the standards from Neuferts. So after quickly reading through all the different types of parking decks, the one design that is most commonly used was chosen. Then using Neuferts and NC stateâs code for multi level parking decks to design the parking deckâs both sloped and non sloped horizontal plates which have minimum width requirements, the staircases on either side with minimum dimensions already set within the code. With most of the design already pre configured within the code we do allow some flexibility with what the user needs.

This tool has a user interface that allows the user to choose what type of parking deck they need and can configure every aspect of the building based on their unique site and requirements.

3.3 Programming Workflow

The first part of the code is focused on creating a user interface where the users are able to input the values that they need so that the parking deck is customised to their

very specific needs.

The user interface stores these values, where one of them is the site boundary that directs the rest of the code.

Once we have the boundary the code then splits the area into 4 parts as described by the chosen type of parking deck, which are then converted into floors and the heights are guided by the user input. Then it is arrayed in the z axis depending on the number of floors required.

Now that we have a floor base for the parking deck we need the walls to cover it up and provide safety skin to the deck. So the code creates walls using the boundary input that was provided with breaks in height (the openings for ventilation) these breaks are influenced by the height that the user provided and change accordingly while keeping the minimum standard.

Now that we have a skin and a base for the parking deck we will now work on structural support. So we use the boundary to map out grid lines that are spaced with the minimum required distance for a standard structural column. Then we place columns at every intersection.

We now need means of egress for the people to exit and the chosen parking deck type has got two stairwells and one of them needs to have an elevator. So we use the userâs input to direct the dimensions of these stairwells that are cut into the base parking deck.

For the parking spaces we have revit read the width of the parking spot and place itself in an array along the floors of the parking deck. So now we can get the maximum number of parking spots immediately.

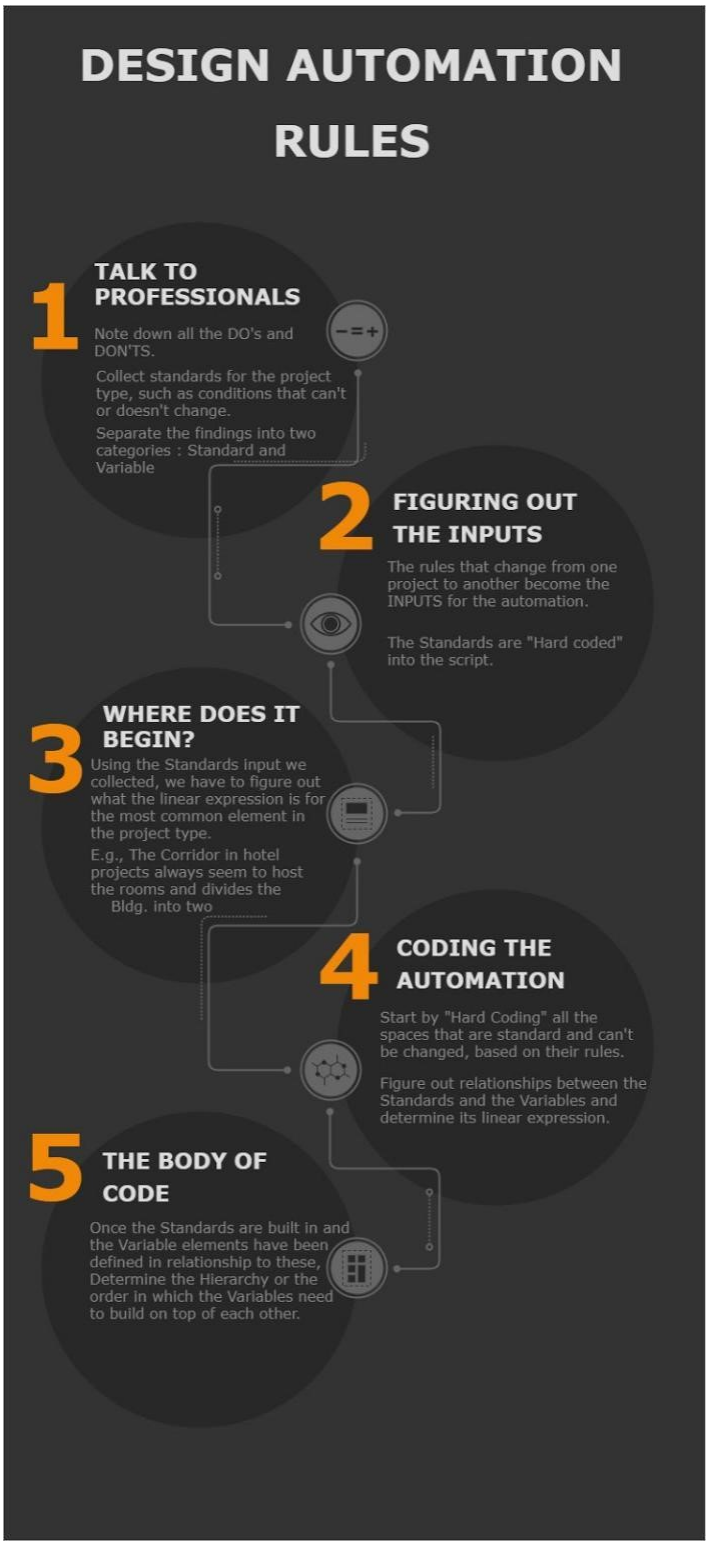
We are also able to find the farthest spot and calculate the distance to the entrance by using the length of each of the floors from the top floor.

We can also wrap the parking deck with apartments around the sides. We use the dimensions that the user provided to create the walls inside. We still use the heights of the parking deck to create the apartment units.

CHAPTER 4: METHODOLOGY

4.1 Introduction

After testing out the parking deck tool and its automation capabilities, limitations, the next step was to automate a project type with a little more function and flow involved. And the hospitality sector seemed to have detailed standards and set of rules that is adhered while designing a hotel of the same type. So I started researching Ho-tel standards to design a program and automate the modelling process. This Process began by understanding and deconstructing the rules of the design of the hotel by talking to 5 different architects about the base rules of designing any hotel, like the chief constraints that would be considered before building/designing. Use and evalu-ate different architects views and opinions on designing a hotel and extract the rules from this transcript. I.e., define the constraints that would likely change(the variables in an algebraic expression) as the main parameters around which the standards or the parameters that dont change is built around to create the logical expression for the programming. The variables will be a part of the user interface for the user to input its values to get the desired output. This process takes place in dynamo for revit, which creates this automation process of designing an entire prototypical hotel based on the created algebraic expression.



(a) Methodology Flow diagram

Figure 4.1: Methodology flow diagram

Revit is a software widely used in the construction field by architects, contractors and engineers due to its BIM capabilities and functionalities. The developers of revit released Dynamo for revit which is a graphical programming interface that allows us to customize our building information workflow. Dynamo also allows us to hack into Revitâs API to automate many of the mundane repetitive tasks required to be performed while modelling a project.

By using dynamoâs ability to hack into revitâs API and its functionality to graph-ically code in many expressions and formulas based on the constraints that are set in revit. It is possible to derive the base âFormulaâ of a particular building type and turn it into a parametric set of rules and codes that can be transformed into a building information model that can be later used to create construction documents directly from.

4.2 The Program Structure

The design of the code will follow very closely to the parking deck but the initial user study reveals all the constraints that a user would want to manipulate or change from one prototypical hotel to another.

1.So just as we began coding the parking deck we would have to create the code for a user interface that is able to retrieve the site boundary and all the other values that will be used to design the hotel prototype.

2.The code needs to have the prototypes plan pre configured so i will be using a prototypical plan to have the base plan laid out but have the length and width of the room as a variable so that it can be changed(this is for the ground floor)

3.The upper floors just have guestrooms on either side of a central corridor, but we need to give the users the option to configure the type of these guestrooms in each floor or provide them the option to make it a typical guestroom. So we divide the parallel sides of the boundary into points that are arrayed with the distance that is

the width of that particular guestroom type.

4.So the user has to give us an input that look like a matrix which say for eg. looks like 3 king, 2 queen, 1 king suite etc., or can even provide us with an excel sheet. Using which we can design the upper floors.

5.The prototype dictates where the elevator goes and so do the stairs but if the site exceeds a certain minimum the code should automatically add in another set of egress.

6.This floor plan is then arrayed in the z axis depending on the number of floors the user needed. Since the furniture in a guestroom remains fairly constant throughout a particular design of hotels, we can program the furniture for each guestroom type before even placing the guestrooms. So now we have furniture and finish plans along with the floor plans completed.

7.We now have a very strong foundational model, we now need to program each room to have a window on the exterior wall and a door on the interior wall.

8.We again use the boundary to program revit to create floors that are arrayed up in height based on the users needs.

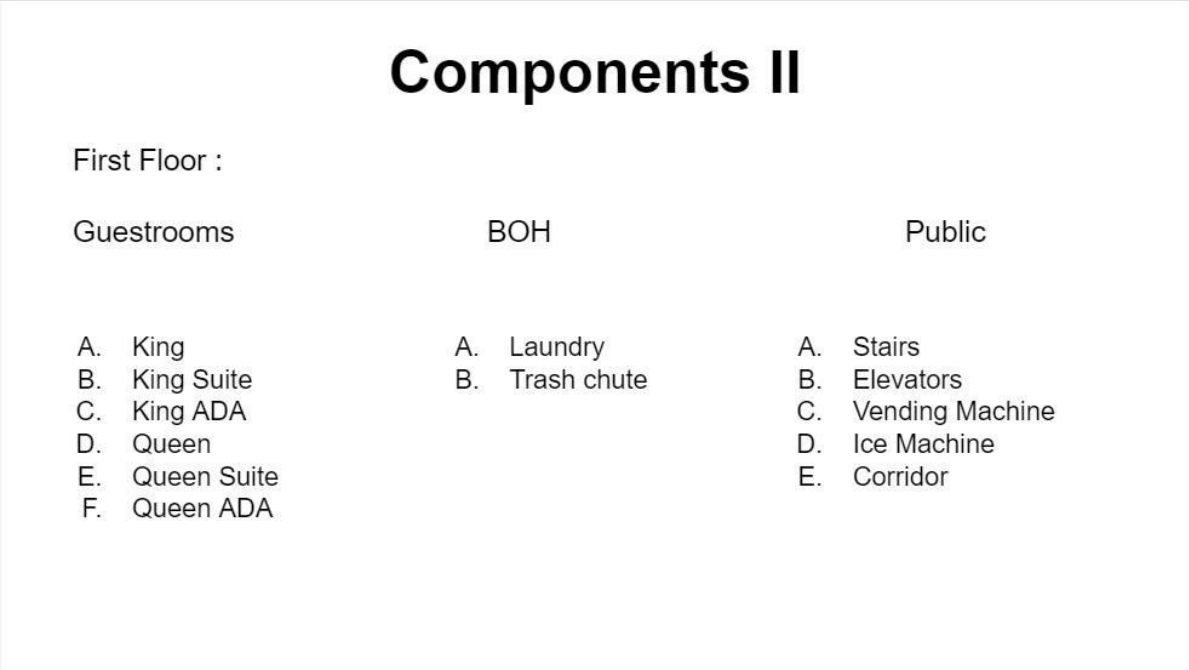
9.We would now have a complete Building INFORMATION Model that meets all requirements for a schematic design phase of submission.

10.This automation will be completed in less than 5 minutes and without the code we will have to wait for a minimum of 3 weeks to find out all the information of the designed building that could be crucial in the early decision making stages.

After creating the said tool from the constraints gathered from the architects and my own experience, it was tested in the architecture firm to collect their valuable critiques and get their opinions to make a better version of the tool from the user experiences.

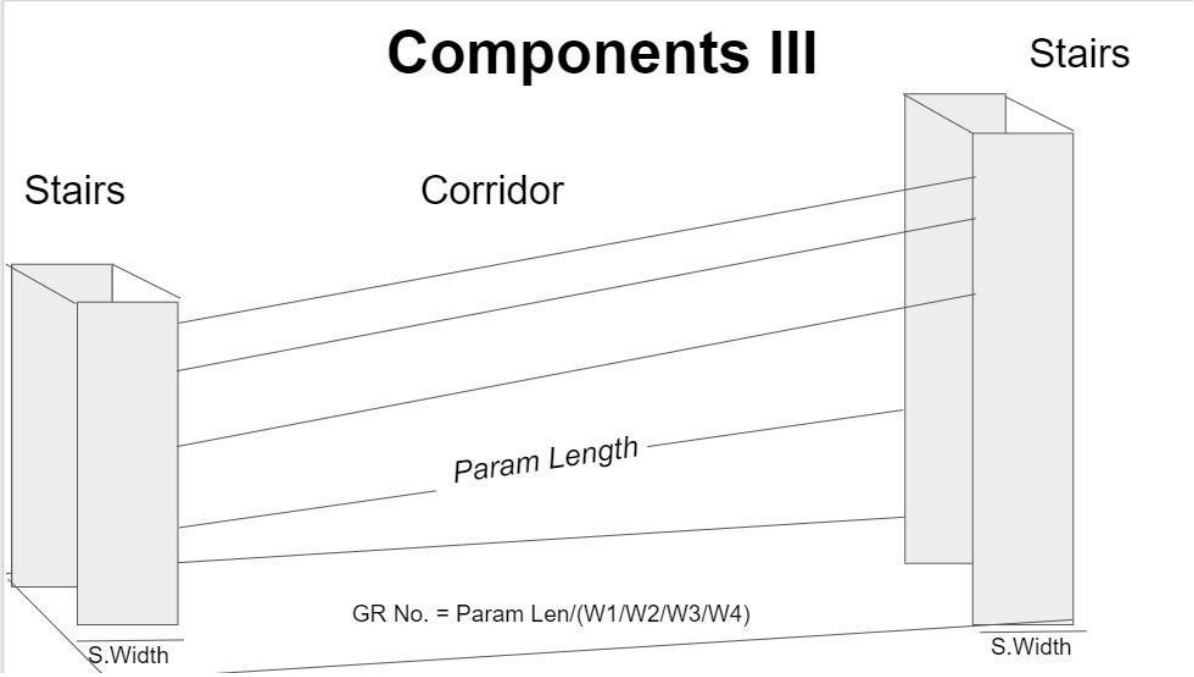
(a) The basic code structure

Figure 4.2: The constants in the ground floor



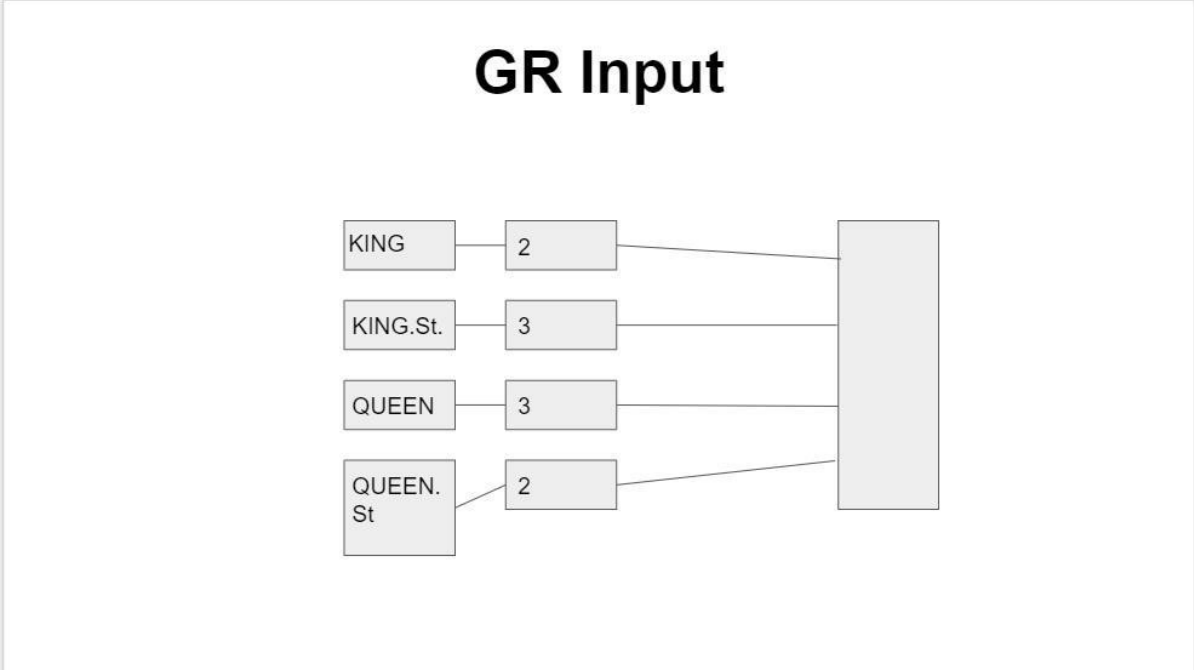
(a) The basic code components

Figure 4.3: The constants in the first floor



(a) Prototypical hotel calculation Diagram

Figure 4.4: Diagrammatic expression of the codes structure for the model



(a) The input for the guest room types

Figure 4.5: The UI to enter GR types data

4.3 Data Collection/ Design Studies

After considering many different building programs and types, I have come to the conclusion that using a hospitality building as a base to create the first parametric building model. Since :

The building design for a particular hotel brand remains the same no matter the site location or budget. (With only minor changes like changes in size of program spaces or number of floor etc.,)

Access to all the prototype drawings and requirements from many different Hotel Brands to be able to formulate a set of rules/constraints based off of their minimum requirement

Perform a case study of the design process and construction of an ongoing Hampton Inn project in greer.

Use historical data and models from past hospitality projects to study the underlying principle and working of a successful hotel.

CHAPTER 5: PSEUDOCODE

The first part of designing the programming part was interviewing three architects who are specialised in designing hotels. These architects were the principals in a firm that primarily designed custom (unique and different from all others) and prototypical (follow a standard set of drawings) hotels. The interview began with the presentation of my thesis goals and what it looks to achieve and how their answers would be a major part of creating the automation program. After which these professionals were asked a couple questions on the decision making process while coming up with the numbers for a hotel design like what would determine the height of the building, the number of floors, the number of guestrooms, the different guestroom types ratio etc., What i learned from their answers was that in a prototype hotel the different program positions and the furniture in all the programs are constant but everything else keeps changing as required by the state's law or the owners budget etc., so these values that are bound to change not just from one project to another but at different phases for the same project would serve as the input parameters for the tool that the user can manipulate and change at will to get the desired result.

So in the case of a prototype Hotel building, most of the spaces already have a predefined dimension to which the architect would have to stick to all the time. So these sizes and dimensions can be hard coded into the script as a part of the main body. This is the easy part of automating an entire building.

The hardest part of automation is to identify where the change might/will occur from one project to another. Such as the site area/boundary is bound to differ from one project to another and would affect the length or width of the building model, so that needs to be parameterised or in other words we need to code the model

automation to fit the site provided by the user and it should have the ability to change/resize itself to fit the new dimensions. Many more basic input parameters can be derived by default and could be set before starting any project type, such as the floor to floor height or the number of floors or the corridor width etc.,

From the discussions I had with the hospitality architects, I determined the main changes they would usually make to a prototype building were the guest room types. They claimed each site/location demanded a different composition of the guest room types(usually King, dbl Queen, King Suite, Queen Suites, King ADA, Queen ADA ADA for the Suite rooms). After taking a closer look at the prototypes and deter-mining the factors for automating this process, I figured out that the guestrooms, Egress, BOH(Laundry/Trash) etc., always shared the corridor. Making the corridor the perfect host to build this building type from.

The corridor for a typical prototype seemed to bisect the building into two equal halves and so by reverse engineering the entire process I started by assigning the corridor space to the given site first and later starting the egress and the guestrooms from either side of the corridor. The pattern always had stairs at the two ends of the corridors as well, followed by laundry spaces on the opposite side, so these spaces are hard coded to follow wherever the corridors began and ended.

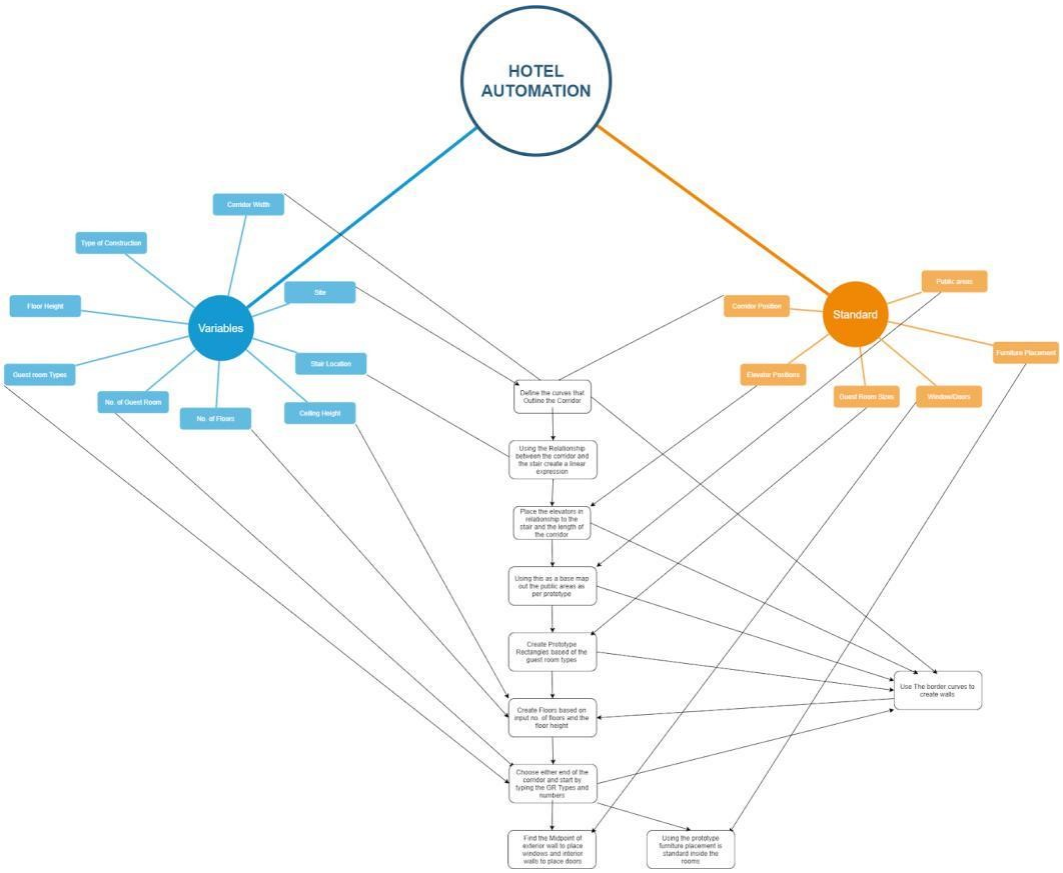
The space in-between is filled with guestrooms and the architects suggested hav-ing 6 different types on one side to create some interesting ups and downs on the facade(since almost every guest room type has the same width but they all differ in length). Using this I created a python script that can take in 6 different names of guest room types following the number of times you need it to be repeated along the corridor to generate the guestrooms.

Revit requires a lot of information to create wall/window models so only a line diagram is drawn in the beginning based on the outline of the boundary, the hard coded dimensioned spaces and the user required GR spaces for the required number of

floors and when the complete single line floor plan is drawn revit is given instructions to turn the outer lines into the outer wall type and the inner lines into the inner wall type, While the points on the exterior walls become windows the points on the interior walls are where doors are placed.

Once this action was successfully completed it was easy to determine the centre of the exterior wall of every guestroom to create the windows and to have alternating doors on the interior wall as to align the bathroom shafts together.(adjacent guest roomâs bathrooms share a shaft and hence alternate in the position inside a guest room)

The last action was to place the relevant furniture items(which are all predefined as to where they need to go and what they should be in the prototype). Since we know the name of each guestroom, I associated each furniture family with its particular guest room type. So when we call for a particular furniture set for that particular bedroom the right one gets placed in the room.



(a) Pseudocode flow Diagram

Figure 5.1: Pseudocode web diagram

CHAPTER 6: CONCLUSIONS

6.1 User Results

Setup

The test users were all employees at the architecture firm that specializes in hotels whose principals volunteered to interview for the initial study for designing the pro-gramming part of the project. The study was made completely voluntary and the users participated out of their own curiosity and interest for the topic.

A laptop with the created program and the necessary hardware requirements was placed in the meeting room, where everyone had gathered. And were asked to use the created tool one by one :

Parking deck : The users were explained how the parking deck tool works and were given a demonstration on the same using the laptop. The demo was very simple, a rectangular site was drawn and used that as my first input after the tool was run. Then the parameters are filled out using the UI and the code does the rest. The model has popped up in 3 minutes or less with the maximum number of parking spots.

Hotel : The rules and the limits of the project was explained followed by a quick demonstration which was very similar to the parking deck but a little more specific with the guest room types and the number of rooms required of that specific GR type in a sequence.

The Users Critique :

All of the users had an architectural background so they were able to quickly understand the premise of the project and successfully recreated what i had performed in the demo for both the parking deck and the hotel but when they were asked to

explore other options or to achieve a new goal that they came up with, the code seemed very inefficient to their needs. The most critique I received for the parking deck was that â It seems to do the job for the one type of parking deck on a rectangular site but what if I wanted a different type of parking deck on a non rectangular site?â This was a very valued point and showed that the code i had created was very limited to what it can do and all its constraints. But it is due to the constraints that complete automation was possible.

The critique was very similar for the parametric hotel as well but for the hotel they wanted more flexibility (being able to customize the furniture of the guestrooms and also be able to manipulate the sizes of the guestrooms. One major critique that was pointed out was that the parking deck automatically places the maximum number of parking spots based on the site dimensions but for the hotel the user has to manually enter the number of guestrooms required for each GR type.

The main reason for this limitation is that the parking spots in a parking deck has a standard size and is repetitively placed one after the other on the floors right after the site is defined but in a hotel with multiple guestroom types with varying length and arbitrary positions, The program cannot exactly determine the position of the guestrooms until the user provides the number of guestrooms required for each type and its location to actually begin the modelling process.

In the event where the position and the number of guestrooms and its different types is a part of the program where the machine decides those numbers for optimal result then we wouldnt be having this issue but we would be giving up "our choice" which is the one feature/role architects do not want to give up.

To address this issue another program was created to test fit the maximum number of guestrooms the user can have in the given site. Which allowed them to visualize the mass and decide the percentages of the different types of guestrooms that are required and use that number as inputs in the code written in revit to late automate

the modelling process. Therefore eliminating the need for the users to manually figure out how many spaces there are in the site to be filled by these different types.

The next versions of these tools should be able to accommodate these needs in one precise tool that is able to calculate the maximum number of guestrooms that can be fit in a site and also provide the users some flexibility on the design of the hotel.

Limitations of automation

Through this research of automating a parking deck design and a hotel it was found that the parking deck design seemed more feasible to the architects than the hotel that was automated. It was also the case when different apartment types were added to the parking deck, the architects wanted more design freedom and choice and complained that the automation inhibits their creativity for designing these apartments. So in Conclusion it was found that the more function and different program types the project contains the level of automation needs to proportionally decrease as with more automation comes more constraints which the the different functions would react against causing the design to crumble

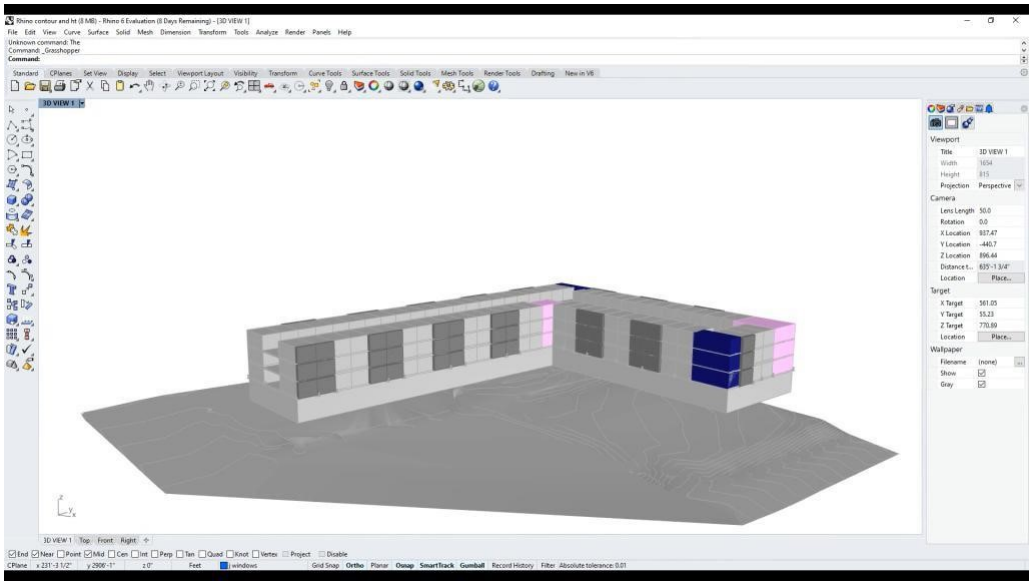
6.2 Post User Critique Design

When architects were asked to use the tool that was created to help automate the process of modelling the prototypical hotel the most common critique received was that they needed the tool to output the maximum number of rooms that can be fit in a site defined by the user.

Although this is possible with dynamo in revit and combine it with the tool that I have created to automate the prototypical hotel design. I decided to use rhino and its parametric tool grasshopper to create a script that can determine the maximum number of apartments since grasshopper has better capabilities to handle general massing and count.

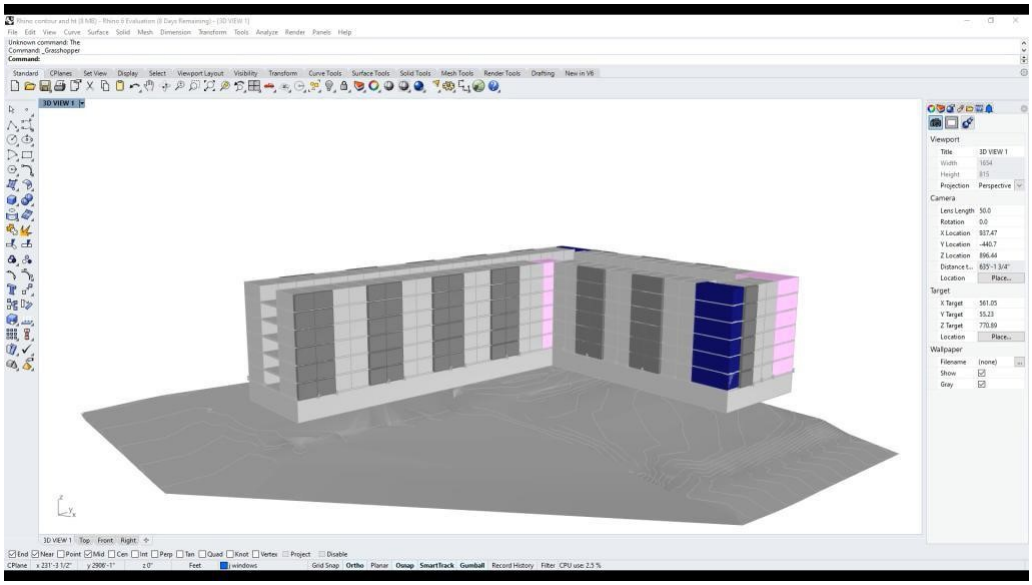
The code part was very simple math that acquires the site boundary provided by the user and divides the outline into points spaced out with the distance between

them being the width of the room provided by the user to mass the rooms in line with the boundary and since it is all parametric the massing adjusts automatically as the user changes the parameters provided such as the number of floors would vary the number of rooms that could be fit and so on...



(a) Parameters set to have 3 floors

Figure 6.1: Grasshopper massing Guestrooms on Site



(a) Parameters set to have 6 floors

Figure 6.2: Grasshopper massing Guestrooms on Site

CHAPTER 7: DESIGN PRECEDENTS

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APPENDIX A: CONSENT FORM

School of Architecture

9201 University City Boulevard, Charlotte, NC 28223-

0001 Consent to Participate in a Research Study

Title of the Project: Parametric BIM Automation

Principal Investigator: [Name: Jashwanth Lakshmanan, Uncc]

Faculty Advisor: [Eric Sauda, Professor, Uncc]

You are invited to participate in a research study. Participation in this research study is voluntary. The information provided is to help you decide whether to participate. If you have any questions, please ask. Important Information You Need to Know

If you choose to participate in this study, you will be asked to use the parametric parking/hotel tool to create a building model of your requirements.

You time commitment will be about 15-20 minutes after which you would have to provide a brief of the experience using the tool.

We will also collect information on how you use the tool and its results.

What benefits might I experience?

You might learn of new technology and tools out there to improve yourself as an architect

You will not benefit directly from being in this study. However, others might benefit because by using a more advanced version of the tool based on your feedback.

What risks might I experience?

There is no known risk.

How will my information be protected?

We plan to publish the results of this study. To protect your privacy, we will not include any information that could identify you. We will protect the con-

fidentiality of the research data by not recording it as the research does not focus on the participants but the way the tool would be used by people in the architecture field.

How will my information be used after the study is over?

After this study is complete, study data may be shared with other researchers for use in other studies or as may be needed as part of publishing our results. The data we share will NOT include information that could identify you. Will I be paid for taking part in this study?

You will be given 5 dollar Amazon gift cards at the completion of participation.

What are the costs of taking part in this study?

No cost

Who can profit from this study?

The study Investigator developed the software application being used in this study. This means the Investigator main gain financial. What are my rights if I take part in this study?

It is up to you to decide to be in this research study. Participating in this study is voluntary. Even if you decide to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer.

Who can answer my questions about this study and my rights as a participant?

For questions about this research, you may contact Jashwanth Lakshmanan at jlakshm1@uncc.edu or at 7046059051. If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Compliance at 704â687â1871 or uncâirb@uncc.edu.

Consent to Participate

By signing this document, you are agreeing to be in this study. Make sure you understand what the study is about before you sign. You will receive a copy of this document for your records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about and my questions so far have been an-swered. I agree to take part in this study. Name (PRINT)

APPENDIX B: QUESTIONNAIRE FOR ARCHITECTS

To get the "Algebraic Expression" or the set of standards the computer has to go through to achieve the feat of modelling an entire hotel / parking deck model based on our constraints, A questionnaire was created for experienced architects to obtain these standards for the coded formula for a hotel that would be completely parametric.

1. What is your Position in the office and the role you play during the initial stages of design?
2. What are the most common constraints that contribute to making a decision about the max height of the hotel?;
3. Is the number of guestrooms fixed for a certain type of hotel project or does it vary based on site extents,locations, budget etc.,;
4. How do you decide on the percentage of the different types of guestrooms for the hotel?
5. If there is a shortage of space for guestrooms how or what would be compensated to satisfy the minimum requirements of the guestrooms?(like shorten public spaces or increase plot areaâŠ)
6. If the public areas like the fitness center or the reception were to be shortened, how would that affect the occupancy of the space or is there a minimum area requirement for all public spaces as well?
7. How does parking affect the design of the hotel building?
8. To achieve the desired number of guestrooms in a large plot, is it preferable to go vertical or horizontal in building construction and why?

9. How would that affect circulation like the number of stairs/elevators?
10. Construction materials and cost
11. If the hotel design was to be LEED certified or energy efficient would that affect the design of the hotel or just the materials and equipment used while constructing the hotel?
12. How do you decide on what type of construction the hotel would be? (wood/metal/concrete etc.,)
13. Would that decision be based upon the desired life expectancy of the building?
14. The site conditions?(such as soil,weather and availability of raw materials)
15. If there is a parametric tool that provides you a BIM model with enough fidelity that it can be submitted as an SD phase drawing, What are the constraints you would like to be in control of (Generally stuff that you might want to change from one project to another)?
16. And what are the stuff you would like the tool to automate or perform by itself without asking for your input?
17. What would you rate the overall quality of the tool?
18. Was the user interface easy to use and informational? Did you have trouble navigating through it or understanding what was being asked?
19. How valuable do you think this tool is ? Would you use it on a daily basis on a day to day basis on the field?