

12-2014

# Strategic Planning Tool Development using Portfolio Decision Analysis

Luis B. Vargas Rojas

*University of Arkansas, Fayetteville*

Follow this and additional works at: <http://scholarworks.uark.edu/etd>

 Part of the [Business Administration, Management, and Operations Commons](#), [Higher Education Administration Commons](#), [Industrial Engineering Commons](#), and the [Operational Research Commons](#)

---

## Recommended Citation

Vargas Rojas, Luis B., "Strategic Planning Tool Development using Portfolio Decision Analysis" (2014). *Theses and Dissertations*. 2034.  
<http://scholarworks.uark.edu/etd/2034>

This Thesis is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of ScholarWorks@UARK. For more information, please contact [scholar@uark.edu](mailto:scholar@uark.edu), [ccmiddle@uark.edu](mailto:ccmiddle@uark.edu).

## Strategic Planning Tool Development using Portfolio Decision Analysis

Strategic Planning Tool Development using Portfolio Decision Analysis

A thesis submitted in partial fulfillment  
of the requirements for the degree  
Master of Science in Industrial Engineering

by

Luis B. Vargas Rojas  
University of Arkansas  
Bachelor of Science in Industrial Engineering, 2013

December 2014  
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

---

Dr. Gregory S. Parnell  
Thesis Director

---

Dr. Edward A. Pohl  
Committee Member

---

Dr. Manuel D. Rossetti  
Committee Member

## **Abstract**

A portfolio decision analysis strategic planning tool was developed for the Facilities Management Office at the University of Arkansas. The tool provides information to support budget allocation decisions based on their Strategic Planning Project List, project attributes (e.g, seat utilization, scheduling preferences, and sustainability rank), and budget constraints. The projects are evaluated using multiobjective decision analysis. We introduce dynamic value functions, which vary the range of the value measures based on the planning horizon, to evaluate the projects). We determine facilities portfolios based on the project values and constraints using Linear Programming. In addition, insightful reports are generated, which provide the stakeholders and decision makers visibility in the data trends that might affect the budget allocation in the future (e.g., student enrollment, fees increase).

## **Acknowledgements**

First and foremost, I would like to thank Dr. Gregory S. Parnell for the valuable support and guidance he has provided throughout the project. His experience and vast knowledge in the field contributed tremendously. I would like to thank Dr. Edward A. Pohl, who made the project initiation and kickoff possible. Being the Industrial Engineering's department head, he encouraged the idea for the project with the Facilities Management team, which was essential to the project's funding. Special thanks to Michael R. Johnson, Associate Vice Chancellor of Facilities Management, which made the project's funding possible, as well as providing extensive information and resources throughout his team. In addition, I would like to thank Jay Honeycutt and Jean E. Mitchell, whose willingness to help and effort in providing information were key for the project's conclusion.

## **Dedication**

This thesis work is dedicated to my family, who I am truly thankful for having in my life. Being a constant source of support and encouragement, they taught me valuable lessons and principles that always encourage me to go forward and be a better person. Thank you for continuous love and support.

## Table of Contents

Chapter 1: Introduction .....	1
Chapter 2: Literature Review .....	2
2.1 Introduction to Decision Analysis Process.....	2
2.2 Value Modeling.....	3
2.3 Portfolio Decision Analysis .....	5
Chapter 3: Background .....	9
3.1 Project Initiation.....	9
3.2 Current Decision Process .....	10
3.3 Research Task .....	10
Chapter 4: Decision Model Development.....	12
4.1 Challenges .....	12
4.2 Decision Analysis Process .....	14
4.3 Selecting the Appropriate Decision Process .....	14
4.4 Framing the Decision .....	16
4.4.1 Vision Statement.....	16
4.4.2 Issue Raising.....	17
4.4.3 Decision Hierarchy .....	18
4.5 Craft Decision Objectives .....	20
4.6 Decision Alternatives .....	23
Chapter 5: Data Sources.....	26
5.1 Central Scheduling Procedures .....	27
5.2 College Net’s X25, R25 .....	28
5.3 Utilization score measures and schedule preferences .....	29
5.4 Facility Condition Assessment Database .....	36
5.5 Enrollment Reports .....	38
Chapter 6: FAMA Strategic Integrated Planning Tool .....	40
6.1 Model Parameters.....	41
6.2 Projects .....	42
6.3 Parameters .....	44
6.4 Budget Availability .....	48
6.5 Swing Weight Matrix .....	51
6.6 Project Assessment.....	57
6.7 Portfolio Assessment.....	61

Chapter 7: Results .....	69
Chapter 8: Conclusions .....	73
8.1 Future Research.....	74
Bibliography .....	76
Appendix A.....	77



## Table of Figures

Figure 2.1 Decision Analysis Process.....	2
Figure 2.2 Information and prioritization in a simple portfolio.....	7
Figure 3.1 Gantt Chart for Thesis Work.....	11
Figure 4.1 Dialogue Decision Process.....	15
Figure 4.2 Issue Identification Matrix.....	17
Figure 4.3 Decision Hierarchy.....	18
Figure 4.4 Value Hierarchy.....	22
Figure 4.5 Facility Renewal and Stewardship Plan Future Targets.....	24
Figure 5.1 Data Sources for Planning Tool.....	26
Figure 5.2 Room utilization per building.....	30
Figure 5.3 Seat utilization per building.....	31
Figure 5.4 Average number of meeting hours per room.....	32
Figure 5.5 Scheduling preferences by Building.....	35
Figure 5.6 FCI levels and FCI ranks.....	36
Figure 5.7 Facility Condition Assessment Example (Kimpel Hall).....	38
Figure 6.1 FAMA Integrated Strategic Planning Tool Main Menu.....	41
Figure 6.2 Project Menu.....	43
Figure 6.3 Tool Parameters.....	44
Figure 6.4 Student Enrollment Regression.....	46
Figure 6.5 Average Number of Credit Hours Regression.....	47
Figure 6.6 Budget Definition in the Tool.....	48
Figure 6.7 Value hierarchy and priorities menu.....	52
Figure 6.8 Priorities Matrix Definition.....	57
Figure 6.9 Project Assessment Example.....	59
Figure 6.10 Value vs. Cost Plot.....	61
Figure 6.11 Football Graphic (Range of possible portfolios).....	63
Figure 6.12 Portfolio Assessment Options.....	67
Figure 7.1 Portfolio Allocation result based on (yes/no) decisions.....	70
Figure 7.2 Portfolio allocation result allowing partial funding.....	71
A.1 University of Arkansas landholdings memo.....	77
A.2 Room Supply vs. Demand.....	78
A.3 Room capacity placement by College.....	79
A.4 Meeting Hours per College.....	80
A.5 Meetings planned per college throughout the day.....	81
A.6 Class Mapping per Room/College.....	82
A.7 Class/Event Time distribution throughout the day.....	83
A.8 Schedule distribution in a business week.....	84
A.9 Weekly Meeting Pattern.....	85
A.10 Enrollment Report Fall 2014.....	86
A.11 Budget Template Breakdown from FAMA.....	87
A.12 Cumulative resources by budget category.....	88
A.13 Piece Chart for Budget Categories.....	89
A.14 Total Resources by budget category.....	90
A.15 Snapshot of X25 and FCA Database Table (Data Source Table).....	91

## **Chapter 1: Introduction**

The purpose of this research was to develop a strategic planning decision support tool, which integrates the information the Facilities Management team at the University of Arkansas needs to recommend decisions on their strategic budget allocation for campus construction and renovation. A literature review set the theoretical background of the thesis. Several published decision analysis papers were reviewed, ultimately setting precedence for a new proposed method called “dynamic multiobjective value functions”. Events and discussions that enabled the thesis development are discussed in the Background chapter. Extensive information and resources were necessary to understand how decisions are currently being made, as well as some historical trends in building utilization and student growth, which are discussed in the methods section. A proposed method of decision analysis is discussed in the Decision Model Development section, which contains the logic for resource allocation. The development of the Strategic Planning Tool is then discussed, the construction of the Excel macro enabled spreadsheet allows the Facilities Management team to gain visibility for their construction decisions. The model provides an optimum portfolio of decisions that helps the FAMA team to guide their yearly construction budgeting. A discussion of results is included in the next section, which highlights some possible assumptions that might be important for the decision makers to consider while interpreting the results from the Strategic Tool. Finally, conclusions are drawn based on the results and conclusions, which encourages encourage future researchers to expand the idea of dynamic multiobjective value functions.

## Chapter 2: Literature Review

### 2.1 Introduction to Decision Analysis Process

The Decision Analysis Process is a decision framework introduced by Gregory S. Parnell and Terry A. Bresnick in their book “Handbook of Decision Analysis”. It is a 10 step process that allows the decision makers to consider every possible aspect of the decision, regardless of its complexity. An illustration of the process is shown below:

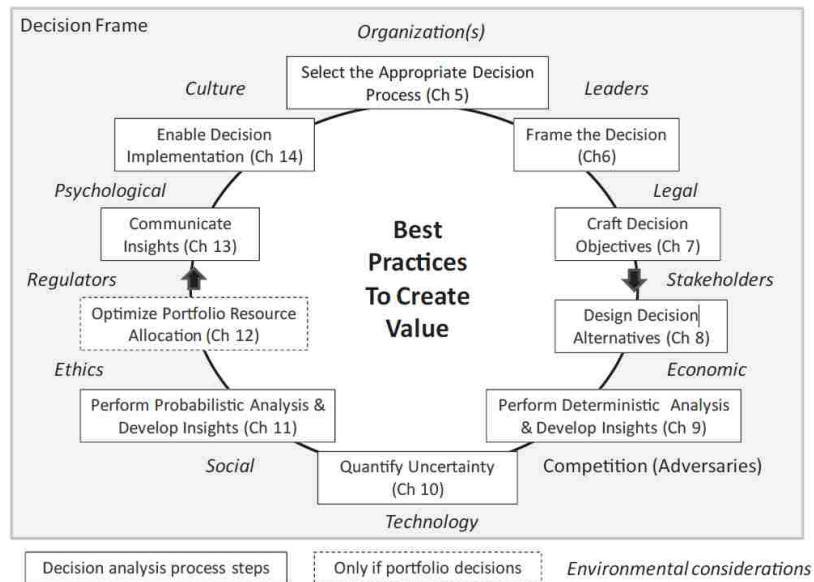


Figure 2.1 Decision Analysis Process

It is an iterative process that can be modified according to the problem being analyzed. It is not necessary to go strictly through the 10 steps, as long as the step omission is justified. As an example, step number 4, *Designing Decision Alternatives*, was omitted from the thesis work because the alternatives were already crafted and designed by the stakeholders. In addition to the steps present in the Decision Analysis Process, we can see that there are 12 environmental factors outside of the Process, inside the Decision Frame. These environmental factors refer to the different ways the decision process can affect the stakeholders and decision makers, as well as the range of consequences present in different categories. Each decision may be affected by

the environmental factors in the Decision Analysis Process. The application of the process to this thesis work is discussed in the Methods Chapter.

## **2.2 Value Modeling**

Value modeling is a systems engineering methodology that has as a main objective the “evaluation of candidate alternatives” (Parnell, Driscoll and Henderson 326). It aims to provide a quantitative/qualitative value to our alternatives. It is highly important to construct the value model in a way that fits the stakeholders’ vision of the alternatives’ value. Research and stakeholder analysis are needed in order to efficiently define our value model. The following key concepts in value modeling allow us understand a defined approach to modeling the stakeholders needs:

*Fundamental Objective:* The main goal or objective the stakeholders are trying to achieve.

*Value Measure:* It assesses a value for each objective that is defined in order to achieve the fundamental objective. Examples can include: the percentage of utilization of a campus building. Depending on the value function’s shape, the value measure will change. Assuming that the function is linear increasing, we can assume that as the building’s utilization increases, the value measure for that objective will increase equally for each equal increment as well.

*Qualitative Value Model:* The stakeholders’ definition of qualitative values. From defining which is the fundamental objective, to defining which specific objectives and value measures are going to define value.

*Functional Value Hierarchy:* The representation of the value model that represents the relationship between the functions, objectives and value measures.

*Weights:* Each value measure will be assigned a “priority” or weight, which defines the importance of each value measure, as well as the range of its measurement scale. The term is

also referred to as “swing weights”, because it assesses the impact of “swinging” the value measure from its worst to best level (range). The traditional approach in defining the range of measurement scale is by defining fixed best and worst scores on a value measure. In the building utilization example, we could define the range of measurement 0 as being the worst, and 100 as being the best. The proposed value model in this thesis work aims to define the range of measurement with an upper boundary defined by historical data and forecasting, which could change as more data is analyzed and considered. Using our previous example, the upper boundary for utilization could be 70% based on the average utilization of each building possible alternative being analyzed. The value measure “swings” from that reduced range of measurement, which as a consequence provides a higher score in a value model in the reduced range as opposed to 0 to 100%. This avoids having a broadly defined scale range which would undervalue the alternatives in earlier time horizons. The concept of “dynamic range value modeling” will be discussed more in depth in Chapter 6.

*Score:* A specific numerical value in the value measure that represents the performance of an alternative.

*Value Function:* “A function that assigns value to a value measure’s score: (Parnell, Driscoll and Henderson 327). It assesses the returns to scale or the value out of the total range of the value measure. Value functions can have different shapes that assess value in a different way over the range of the value measure

Room utilization percentage in a building is a typical example of a linear increasing value function shape. As the room utilization in a building increase, the building will technically have more scheduled classes and more students, therefore, it has more value as opposed to a building which is barely used and has a really low room utilization percentage.

Value functions can either be discrete or continuous, as long as they represent and assign value to each possible score in the value measure. A specific function can have one or more objectives, as long as each objective is defined by at least a value measure. Each objective is going to have a “priority” or weight that will assess importance in respect to the total value of an alternative. The sum of the priorities must equal to 1. As an example, we can assume that the decision objective is to provide high quality, sustainable facilities for the U of A, where the alternatives are the prospective buildings to be constructed, and the functions being: Improve classroom and laboratory space, improve facilities sustainability, and improve research space. The value hierarchy provides the structure of how value is defined for each alternative, so in the case that the decision makers would like to decide for a single alternative, they would simply pick up the best alternative based on highest value. But what about other quantitative factors that drive the majority of the decisions we make today, such as money? Going back to the construction example, we might have a project that provides the highest value compared to other alternatives, but might cost us 10 times to fund the project than the others. The decision makers might end up picking a building that even though it does not provide the highest value, it might be the cheapest option. At the end, the decision makers are the ones that make the call. In addition to the previous statement, what happens if there is a budget available, and more than one option or alternative can be selected? This is called Portfolio Decision Analysis, which is discussed in the next section.

### **2.3 Portfolio Decision Analysis**

According to the “Portfolio Decision Analysis: Improved Methods for Resources Allocation”, which is a book contributed by numerous authors in the Decision Analysis field, Portfolio Decision Analysis (PDA) can be defined as “a body of theory, methods and practice which seeks

to help decision makers make informed selections from a set of alternatives through mathematical modeling (Keisler). Based on the previous definition, there are two main things that stand out. First, the purpose of PDA is to support decision makers. Portfolio decision analysis does not make the decision for the decision makers. PDA is in its majority quantitative, so there are usually qualitative factors that need to be considered by the decision makers before making the final decision. Second, the mathematical modeling is adjusted based on the needs of the stakeholders. Optimization constraints or value measures changes are just some examples of how the mathematical modeling might change according to the context of the decision and the decision makers' guidance.

A single decision is the same as a constrained portfolio analysis to select one alternative. A set of decisions provide more value compared to a single solution. If we assume that partial funding is possible for construction alternatives, we can define a constraint that would require at least a fixed percentage of the total cost of the alternative, like 50% as an example. However, the more constraints we add into the system, the less the potential value of the portfolio since active constraints reduce the decision space.

PDA has multiple applications, ranging from Financial Portfolio budget allocation, to selection of new possible vaccines or medicines in the drug industry. The alternative screening and the amount of research and development in the previous examples might differ significantly, but the idea behind the selection is the same, select alternatives that provide the most value for given resources.

Jeffrey Keisler's chapter on "Portfolio Decision Quality" (Keisler) provides us an additional understanding of how the value of a portfolio depends on characteristics of portfolio decisions,

as well as the cost of the alternatives. He discusses the tradeoff between increasing precision of the alternatives' value versus cost estimates in the portfolio decision analysis. An example is provided that allows understanding the importance of information and prioritization, which is shown in the following figure:

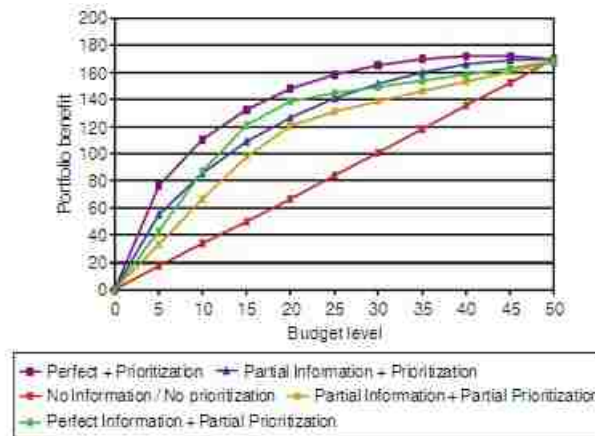


Figure 2.2 Information and prioritization in a simple portfolio

If there is no prioritization or information included in the portfolio, the portfolio benefit will follow a linear curve. As the quality of the prioritization method or the information that is used increases, the portfolio benefit will increase as well. The figure is an example of how perfect information and prioritization provides a significant value increase in the portfolio for not much of a budget increase. The partial prioritization illustrated in the figure is how priority index, one common method used in decision analysis, increases the value of the portfolio as opposed to no prioritization or information. Priority index is used to construct the portfolio's scope in the thesis work, which is discussed in the Chapter 5.

Lawrence D. Phillips on Chapter 3 of the "Portfolio Decision Analysis" (Phillips) book discusses in a similar way the idea of priority index. He introduces "risk" as part of the value ratio that



allows us to understand how prioritization applies to the thesis work. The equation mentioned in the chapter is the following:

$$PI = \frac{\text{Risk adjusted benefit}}{\text{Cost}}$$

Barbara Fasolo, Alec Morton, and Detlof von Winterfeldt in their “Behavioral Issues in Portfolio Decision Analysis” chapter warn us about how modeling should be effectively enough to avoid going astray (Fasolo, Morton and Detlof von 151). Several mistakes can occur while defining the model that might incorrectly assesses value, and as a consequence, provide inaccurate results. It is mentioned how decision makers (DMs) can erroneously assess value functions that mislead to an incorrect decision. “The benefits can be incorrectly defined for a particular project, focusing on a single dimension of benefits where multiple benefits are relevant” (Fasolo, Morton and Detlof von 151). Incorrectly defining project cost or the budget available for the alternatives is another common mistake DMs should be careful about. Underestimating the alternatives’ cost can lead to overestimating the budget constraint. On the contrary, overestimating the alternatives’ cost will underestimate the budget constraint. Finally, the DMs might accurately define the alternatives cost as well as the function’s shape and weights, but incorrectly defining the optimization problem. Omitting or adding irrelevant constraints will produce unreliable results that could mislead DMs by producing incorrect solutions. In reality, there is no decision model that defines the problem we are dealing with perfectly, however, the model should be accurate enough to give us an understanding of what the current problem is, as well as the solution to that defined problem. Decision framing is a useful technique to correctly define the optimization problem, which is discussed in section 4.4.

## Chapter 3: Background

### 3.1 Project Initiation

Unprecedented enrollment increase in the past years has forced the University of Arkansas to undertake one of its largest, longest construction and renovation program in its history.

Chancellor David G. Gearhart has mentioned that in order for the University to deliver academic excellence, they should establish goals and milestones for its renovation program. Becoming a top 50 public research university by 2021 is one of the primary goals. The scale of change has been astonishing, which is forcing the University to consider Facilities Management portfolio decision analysis methods of resource allocation for their prospective building renovation and constructions. The idea was suggested by Dr. Edward A Pohl, current Industrial Engineering department head at the University of Arkansas, to Mike Johnson, Associate Vice Chancellor for Facilities. Being part of the Decision Modeling class, I was given the opportunity to develop the mathematical model using Multiple Objective Decision Analysis (MODA) and Portfolio Decision Analysis. After the class was finalized, the growing interest in the project led me to take an additional class in Portfolio Decision Analysis that would allow me to further understand the theoretical concepts needed for the future thesis. The fall semester of 2014, Mike Johnson decided to fund the thesis to make the computer based tool development possible. It is important to mention that FAMA is not in charge of all the building renovations and infrastructure on campus. The Athletics department has their own funding and resource allocation decisions. Their budgeting sources come from different entities. The financial sources used by the Facilities Management Office for construction and funding of their projects will be explained in the *Value Modeling* section.

### **3.2 Current Decision Process**

Before the thesis' development, building recommendations were based on FAMA analysis and facility committee recommendations. Mike Johnson's team worked together and held several meetings throughout the year to consolidate the Facility Renewal Future Targets Plan. The Facilities Renewal Plan is then presented by Chancellor Gearhart to the Board of Trustees. The recommendations are approved or rejected by the Board. In addition to the Renewal Plan Approval, the majority of the decisions have to go to by the same Board of Trustees. In the case the Facilities Management team would want to push for a tuition increase in their Facilities Fee paid for each student in the University, which as a consequence would give them additional available budget, it would still have to go through the approval procedures described previously. Another example could be issuing bonds to investors for a specific year to fund-raise critical projects that have to be delivered. Despite the fact that people with vast experience in different fields provide inputs to these decisions, there were still limitations and constraints in the current process that where seen as opportunity for improvement.

### **3.3 Research Task**

Increasing the research funding as well as research space is one of the objectives that are described in the "Transforming the Flagship". Cultural aspects and building sustainability are also two other factors taken into consideration. FAMA has several measures that would provide value to the alternatives, however, there was no process until this thesis work that would allow an integrated quantitative analysis of the portfolio. Each director would provide feedback of the best of their abilities, considering that each one has different technical and professional backgrounds. Unprecedented enrollment in the University these past years has generated a higher than expect budget for the Facilities Management Office to invest. Mike Johnson agreed to

partner with the Industrial Engineering department to develop an integrated computer based model that would assess the value of each alternative.

The following is a Gantt chart that represents the tasks as well as the timelines for each part of the thesis work:

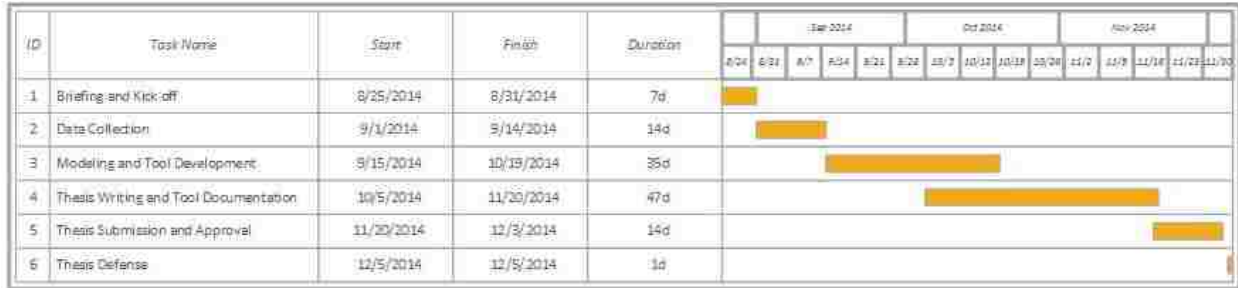


Figure 3.1 Gantt Chart for Thesis Work

Keeping the deadlines portrayed in the figure was essential to avoid getting caught in some phase that might need additional work hours based on continuous feedback provided by the decision makers such as the *Modeling and Tool Development* task.

In order to first understand the right decision process that should be modeled, as well as the mathematical concepts that would be needed in order to capture FAMA stakeholders needs, the Decision Analysis Process was used, which is discussed in the next chapter.

## Chapter 4: Decision Model Development

### 4.1 Challenges

We begin by discussing soft skills as well as challenges that were taken into consideration while in the data gathering and model development phase of the project.

Human beings do not base their decisions solely on simple math. As simple as a decision can be, there might be some added complexity that serves as a trade –off between the interests of the decision makers, an additional factor that needs to be considered into a decision. The more complex the decision, the higher the level of understanding and analysis prior to “pulling the trigger”. Usually complex decisions, such as the one being studied in this work, involve multiple stakeholders, all of them with different perspective and leadership styles. The analyst’s responsibility is to be a facilitator between these multiple stakeholders, being able to engage in multiple meetings to make a common consensus among people. Once the common ground has been defined, the stakeholders should discuss the qualitative factors that might be needed to be included in the analysis, with constant feedback throughout the modeling process.

Because of the differences among different stakeholders, previous case studies have shown how common it is to get involved with “decision traps”, which usually hinder the project’s development and the system as a whole. Terry A. Bresnick provides us with some of the most common decision traps we usually experience in these processes that were applicable to the thesis work (Parnell, Bresnick and Tani 34-36):

1. Inadequate problem formulation: “Analysts often under constrain or over constrain the problem statement” (Parnell, Bresnick and Tani 35). It is really important to have the stakeholders’ needs and mathematical modeling in the same page. Analysts often believe that over constraining the model is beneficial in the sense that more complex formulation

is a way of showing off technical skills and knowledge, but stakeholders often discard such analyses because they are not realistic.

2. Decision paralysis by waiting for “all of the data”. There is seldom a project where the analyst will have all the data he/she required. Assumptions are often made with the decision makers’ approval. The analyst should be able to make the judgment on whether he considers that he has enough available information to initiate the analysis or not. Waiting for non-critical information might hinder the project’s deadlines and deliverables.
3. Looking for a 100% solution: The analyst should use its own judgment and know where to stop modeling. There will always be additional features inside the modeling that can be added. It is more beneficial to show an 80% accurate model in time that 100% model solution that missed a critical deadline. In addition to decision traps, the analyst and stakeholders often get influenced by cognitive biases. According to Parnell, “Cognitive biases are mental errors caused by our simplified information processing strategies, they are mental errors that are consistent and predictable” (Parnell, Bresnick and Tani 35). Below are two examples applicable to the thesis work that affects and influences the stakeholders’ decisions:

**Information bias:** It is the impulse or necessity of looking out for information even if it doesn’t add any value to the project. Data research requires time and dedication, to it is important for the analyst to know if whether data gathering will be something beneficial for the project.

**Recency effect:** Refers to adding more importance in current events as opposed to older ones. As an example, the University of Arkansas has seen unprecedented high student enrollment

in the past 4 years, however, this does not mean that the current trend is more relevant than previous years. The recent student growth might just be temporal, so it is important to consider the big picture.

#### **4.2 Decision Analysis Process**

A decision framework was necessary in order to effectively tackle the tasks and deliverables of the thesis work. The Decision Analysis Process, previously mentioned in the *Literature Review* chapter, provided the most adequate framework that allowed to correctly define which decision process was going to be used. It defined how the modeling development was going to be held, what assumptions and constraints needed to be considered in order to reflect what the stakeholders wanted, as well as an implementation procedure that allowed the new process to take place. The decision framework was chronologically used according to its applicability with the thesis work. Selecting the Appropriate Decision Process was the first step to be considered, which is discussed in the next section.

#### **4.3 Selecting the Appropriate Decision Process**

There are several decision processes in practice, some of them being currently best practices, as well as some being considered flawed. We used the dialog decision process. Dialogue Decision Process: It is a continuous structured dialogue among two parties: (1) the Decision Board, which are the decision makers/ customers that will be evaluating/implementing the project and (2) Decision Team, which are the analysts in charge of gathering all the information required, modeling the new process that is going to be used, and finally discussing with the decision makers about how is the implementation going to be handled. In each one of the phases, meetings are conducted to ensure that both parties are in the same page, and that the new process





analyst to get some feedback based on the information gathered and the stakeholders' knowledge to include in the computer based tool.

#### **4.4 Framing the Decision**

Creating a good decision frame is fundamental to achieving the correct objectives that have been set by the stakeholders. “We did a great job on solving the wrong problem” or “We tried to solve everything and we never got anywhere” (Parnell, Bresnick and Tani 110) are several examples of how incorrectly defining the decision frame can cause unsatisfactory deliverables. We used three of the decision framing tools recommended by The *Handbook of Decision Analysis*.

##### **4.4.1 Vision Statement**

The vision statement uses three fundamental questions.

The first question, “What are we going to do?” refers to which steps are going to be taken in order to achieve the desired goal. The answer resides on the idea that the FAMA stakeholders wanted an unbiased, quantitative computer based tool that would allow them to define value on their construction projects, as well as providing guidance to possible set of decisions based on such model. The second question, “Why are we doing this?” refers to the motivation/reasons for the new process. Finally, the third question, “How will we know that we have succeeded?” refers to whether the new process is a success based on the stakeholders' comfort with the model and preferences, rather than the outcome after making the decision. Based on the three questions, the vision statement for the thesis work would be:

“(1) An integrated strategic planning computer based tool will be developed to assess value for the Facilities Management prospective construction alternatives (2) This will be done to allow the stakeholders to get additional understanding when making budget allocation decisions based

on their available budget (3) Success will be evident whenever the stakeholders agree with the development and new procedures for budget allocation decisions, agreeing with a model that is consistent with the University of Arkansas’ Transforming the Flagship objectives”.

#### 4.4.2 Issue Raising

Issue Raising refers to defining all the stakeholders that should be considered in the analysis, as well as identifying which possible environmental factors are applicable to each one of these stakeholders. Whenever we are dealing with cross functional projects, there is often the case where a group of stakeholders has different preferences or objectives than others. The purpose of issue raising is to identify all issues that might arise because of the new decision process. The issue matrix is a useful tool to summarize the issues. Based on conversation with stakeholders, the following issue matrix was developed:

		Decision Makers/Stakeholders					
Environmental Factors	Environmental Factors	Facilities Management	Architects	Students	Deans & Colleges	Neighbors	State Government
	Economic	Budget Constraint Bond Issuing	Cost Overruns Delays Skilled Labor	Facility Fee	Fair Budget Allocation	Increased traffic due to constructions	Taxes
	Emotional			Resistance to Change		Resistance to change	
	Historical	Past Cost Overruns	Past Cost Overruns				Past Project Conflicts
	Legal	Allocation Compliance	Licensed projects		Building Authorizations		Adheres to Legal State Requirements
	Moral/Ethical	Allocation Ethics	Construction Ethics		Project Ethics		Ethics in Regulation
	Organizational	Project Management Allocation	Project Assignment		Project assignment		
	Security		Adhere construction standards				
	Social						
	Technological		IT technological equirements		Technological Requirements		

Figure 4.2 Issue Identification Matrix

The previous figure illustrates the relationships we were able to identify between the applicable stakeholders and the environmental factors. Each one of these relations will affect the decision

process, so it is crucial for the Facilities Management Team, to keep in mind that implementing a new decision process will affect the stakeholders identified in the matrix.

#### 4.4.3 Decision Hierarchy

“The decision hierarchy is a valuable conceptual tool for defining the scope of the decision” (Parnell, Bresnick and Tani 119). It is divided into three levels. The first level being the one that involves high-level decisions that have been already made. The middle level being the one contains decisions in scope as well as the decision constraints. The third level refers to decisions that cannot be fully defined at the moment and might have to be delegated in a later phase. Usually implementation decisions are in the third level of the decision hierarchy. Based on conversations with the FAMA stakeholders, the following decision hierarchy was constructed:

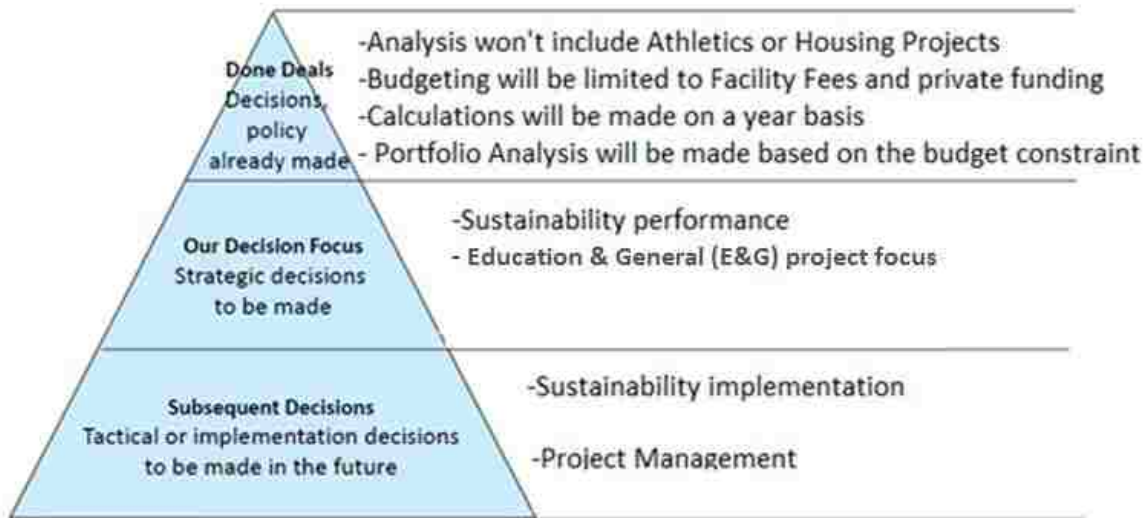


Figure 4.3 Decision Hierarchy

Based on the decision hierarchy shown previously, we can see that there are 4 main policies that we consider as done deals and that will narrow down the scope of the project and the alternatives. The first, being the one that the analysis won't include any construction considered by the Athletic or Housing departments, is a defined policy because both of them are separate

entities that do not share the same sources of funding as FAMA does. Grants and private funding are processed in a different way in each department. Since the FAMA stakeholders are ultimately the customer, different construction projects defined outside of FAMA's scope are not considered. Inside each alternative, there might be special sources of funding that could be allocated to a specific project. For development simplicity, the sources of funding an alternative can have are limited to 2 categories. Facilities fee and private funding categories. The majority of the projects have a lifespan of more than a year, so for modeling purposes, each project is annualized over a defined planning horizon, which is adjusted according to defined variables in a yearly based. The *FAMA Strategic Integrated Planning Tool* chapter discusses more in depth how these adjustments are made. Finally, the portfolio allocation is defined by a budget constraint which is the sum of all the different sources the Facilities Management team expect in a year per year basis (also discussed in Chapter 6).

Inside the decisions that have to be made to define the stakeholder's focus, sustainability is among the first category that is considered. In the past years, improved sustainability has been a path that several departments in the University have opted to follow, FAMA is no exception. By increasing the sustainability factor in their buildings, the department is able to get funding incentives for the government as a prize for this focus. Stakeholders decided that even though it shouldn't be the most important factor considered in the mathematical development, it should still be assigned a portion of an alternative's value. It is one of the objectives portrayed in the Chancellor's plan stated in the "Transforming the Flagship" document.

The vision stated in the same document proposes that by 2021, "The University of Arkansas will be recognized as one of the nation's top 50 Public Research universities" (Transforming the Flagship 2). Additional research space is needed in order to achieve this vision, which should be

considered when modeling the way the computer based tool provides guidance decisions to the stakeholders. Finally, FAMA is in charge of construction projects that go beyond Education and General (E&G). There might be some special projects such as the construction of a new parking lot that is inside FAMA's scope, but that do not provides as much importance as construction projects that will provide educational value to the students.

In the subsequent decisions level, we can mention as examples, two different categories that are considered. The first one being sustainability implementation. The people responsible for the construction implementation should take sustainability into consideration, based on the previous discussions with the FAMA stakeholders. Sustainability planning is as important as its execution. In addition, project management skills are required to ensure implementation goes smoothly and without any problems, considering the requirements and constraints set by the stakeholders.

#### **4.5 Craft Decision Objectives**

The section discusses how developing the appropriate functions, objectives and value measures should be considered before actually exploring the set of alternatives. Usually identifying the objectives is “more art than science” (Parnell, Bresnick and Tani 142). The stakeholders first wanted a fundamental objective that would be consistent with the objectives presented in the *Transforming the Flagship* document, as well as providing a reliable value assessment for each construction alternative. Based on several discussions with Jay Huneycutt and Peggy Comer, they agreed that Scheduling and Utilization where going to be among the top priorities in the objectives definition. However, it would be necessary to break down these two categories further down. Jay worked previously with the Central Scheduling Team at the Registrar Office in the University of Arkansas, and he was aware that they had software that had the data gathering capabilities of gathering enough information to accurately assess value to the alternatives. The

software and different data sources are later discussed in the *Data Sources* Chapter. The stakeholders mentioned how the current decision process would still need to be considered as one value measure in the new model. Even though the number of scheduled hours per building, was not a measure that was tracked at the time in a weekly basis, Central Scheduling had an average figure of the number of events per room that took place in each building. The objective would reflect the demand of scheduling based on the number of students requesting that specific alternative, which ultimately satisfied the stakeholders to include it as one value measure. The average utilization per building would be evaluated in a similar context as the previous one, in a per room basis, however, the utilization was an objective that had to be broken down in two. Room Utilization and Seat Utilization. The first one would indicate the percentage of a business day (7:00 AM to 5 PM) a specific room was empty or not, and then doing a weighted average based on the room capability to have a building average. The second utilization would refer to the number of seats occupied whenever a room is scheduled. The idea here was to the maximum number of scheduled rooms in a building with the maximum amount of students in the room. All these three initial objectives were grouped in a single function, which was to Improve Building Utilization.

Objective number 11 in the “Transforming the Flagship” document states that “sustainability should be promoted across all University of Arkansas programs and activities” (Transforming the Flagship 2). In the initial kickoff meeting, Mike Johnson emphasized the importance of adhering with these practices and considers sustainability in the mathematical development and value hierarchy. Because of the previous statement, Consider sustainability was defined as the second function in the value hierarchy. Since sustainability was a new trending topic that was observed not that long ago, gathering data for the specific objective and value measure was a

concern. Sources provided by the Facilities Management team allowed this data gathering which is explained in the *Data Sources* chapter. Finally, the stakeholders mentioned how there were some differences in scheduling preferences when reserving a room for a specific class. In order to ensure academic excellence, the stakeholders needed to make sure that the room available had the capabilities and equipment that the class required. Some examples are a projector, a computer, among others. A third function was defined to capture the previous concerns, which was labeled as “Achieve Scheduling Preferences”. The function would be defined by a single objective (Max Preferences Measurements) measured by a single value measure, % of scheduling compliance.

The following figure is an illustration that represents the finalized value hierarchy built by the analyst and the stakeholders:

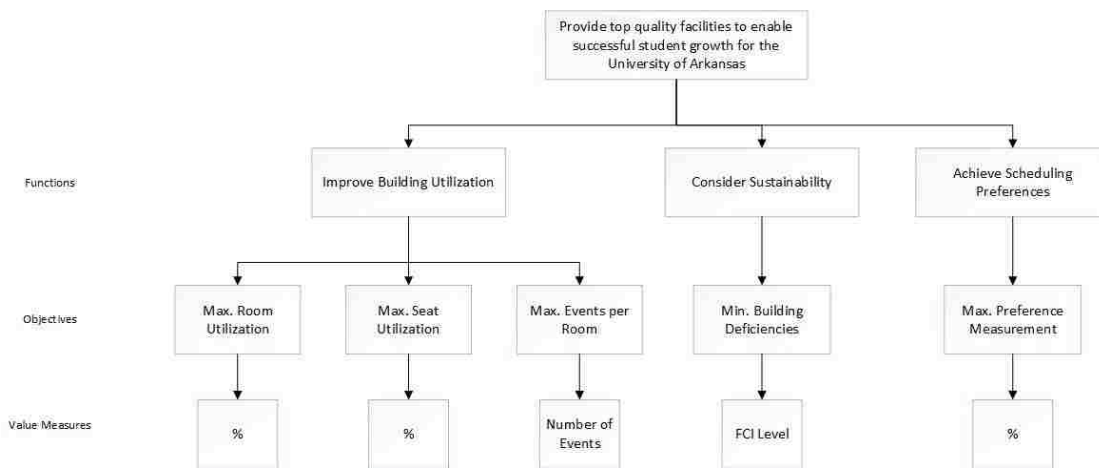


Figure 4.4 Value Hierarchy

The proposed value hierarchy provides the three functions that the stakeholders believe to define the value of the construction alternatives. For each function, objectives and value measures are defined. The alternatives to be considered/ evaluated are discussed in the next section.

#### **4.6 Decision Alternatives**

The Handbook of Decision Analysis provides some useful tools to develop creative and feasible alternatives to be assessed by the value hierarchy; however, in this case, FAMA provided the projects the list of projects changed throughout the thesis work. The table in the following page represents the final construction project list defined by the FAMA stakeholders:



	Project Name	Category	Year Built	GSF	Private Funds / GIF / Grants / PPV (millions)	Facility Fee Bonds (millions)	Total Project Cost
1	KIMPEL HALL / CLASSROOM BLOCK (COMPLETION)	*Renovation	1972	73,240	(Note 1)	\$9.56	\$9,559,758
2	SCIENCE BUILDING (COMPLETION)	*Renovation	1968	53,748	(Note 2)	\$4.95	\$4,944,189
3	FINE ARTS CENTER (WHOLE BUILDING)	*Restoration/Reno	1951	116,915	\$10.00	\$10.82	\$20,823,165
4	LIBRARY OFFSITE STORAGE BUILDING (STACKS REMOVED)	New	TBD	20,000	N/A	\$11.41	\$11,412,627
				Up to 100		\$15.00 -	\$20,000,000 -
5	PLAYING FIELDS FOR UNIVERSITY RECREATION (THREE SITES)	New	NEW	Acres	\$5.00 - \$11.00	\$20.00	\$31,000,000
6	BUSINESS BUILDING / SYSTEMS RENEWAL (PARTIAL)	*Renovation	1977	116,022	\$15.00	\$5.00	\$20,000,000
	RESEARCH CENTER AT ARKANSAS RESEARCH & TECHNOLOGY			Up to			\$20,000,000 -
7	PARK	New	NEW	75,000	\$15.00 - \$25.00	\$5.00 - \$7.00	\$32,000,000
8	HUMAN ENVIRONMENTAL SCIENCES BUILDING (COMPLETION)	*Restoration/Reno	1940	33,395	N/A	\$9.80	\$9,795,619
9	JOHN A WHITE JR ENGINEERING HALL (COMPLETION)	*Restoration/Addition	1927	61,311	\$10.00	\$9.58	\$19,580,820
	ARKANSAS UNION / CONNECTIONS & NORTH TERRACE						
10	PAVILION	New	NEW	10,500	\$3.00	\$3.00	\$6,000,000
11	MEMORIAL HALL (COMPLETION-INTERIOR)	*Restoration/Reno	1940	59,749	(Note 3)	\$16.85	\$16,845,092
12	MULLINS LIBRARY (REPURPOSE STACK AREA)	*Renovation	1968	69,260	(Note 4)	\$15.44	\$15,438,390
13	AGRICULTURE BUILDING (WHOLE BUILDING)	*Restoration/Reno	1927	52,415	\$10.00	\$8.72	\$18,721,361
	NANOSCALE MATERIAL SCIENCE & ENG / THIRD FLOOR LAB						
14	BUILD OUT	New (Interior Only)	2011	6,790	\$5.00	\$0.99	\$5,990,855
	CENTRAL QUAD RENOVATION & EXPANSION / WEST TERRACE						
15	MULLINS MODIFICATIONS	New	NEW	N/A	\$2.00	\$6.00	\$8,000,000
16	CAMPUS NORTH / SOUTH ENTRANCES RENEWAL & UPGRADE	New	NEW	N/A	\$0.00	\$2.00	\$2,000,000
	<b>Total (FY17 Dollars)</b>				\$75.00 - \$91.00	\$134.12 - \$141.12	<b>\$209,111,876 - \$232,111,876</b>

\*Roofs all replaced/new between 2003-2014

Notes:

- 1) Classroom Naming Opportunities
- 2) Teaching Lab Naming Opportunities
- 3) Ballroom Naming Opportunities
- 4) Student Study Commons Naming Opportunities

Comments:

FNAR: Naming Opportunity  
WCOB: Total reflects whole building renovation (was \$10,746,788)  
ARKU: \$3M (reflects \$1M Private / \$2M Student Affairs) and \$3M

Figure 4.5 Facility Renewal and Stewardship Plan Future Targets

As discussed in the *Decision Hierarchy* section, the Athletics and Housing construction projects are not considered in the project list. The list provides the funding required, both private and facilities fee based for each one of the alternatives. There are some alternatives that are defined by a range as opposed to a fixed value. In the private funding piece, there is uncertainty of how well the fundraising campaign for the University of Arkansas will go in the facilities fee funding category, even though the trend for student enrollment can be calculated, it cannot be predicted with 100% certainty. The range provided in the total FY17 dollars row is the estimated amount required to fund all the projects in the list. It is important to highlight that the list of alternatives illustrated in Figure 4.5 do not have to be executed in its entirety. Even though unprecedented enrollment increases and more than expected funding are two current trends, the available budget most likely will not exceed half of the total project list. The list being over a defined planning horizon of 3 years raised some interesting issues. The discount rate of money, as well as any additional increase in the student fee had to be considered. Ignoring these variables might understate or overstate the available budget over the planning horizon.

The following section discusses the development phase of the thesis work. From the data sources that defined the projects, to how the computer based tool was constructed, as well as the mathematical modeling used in the portfolio assessment.

## Chapter 5: Data Sources

Before diving into how the thesis was mathematically modeled, it is important to understand where the data sources. Each one of the five objectives defined previously, as well as the budget constraint, were defined by four different sources illustrated below:

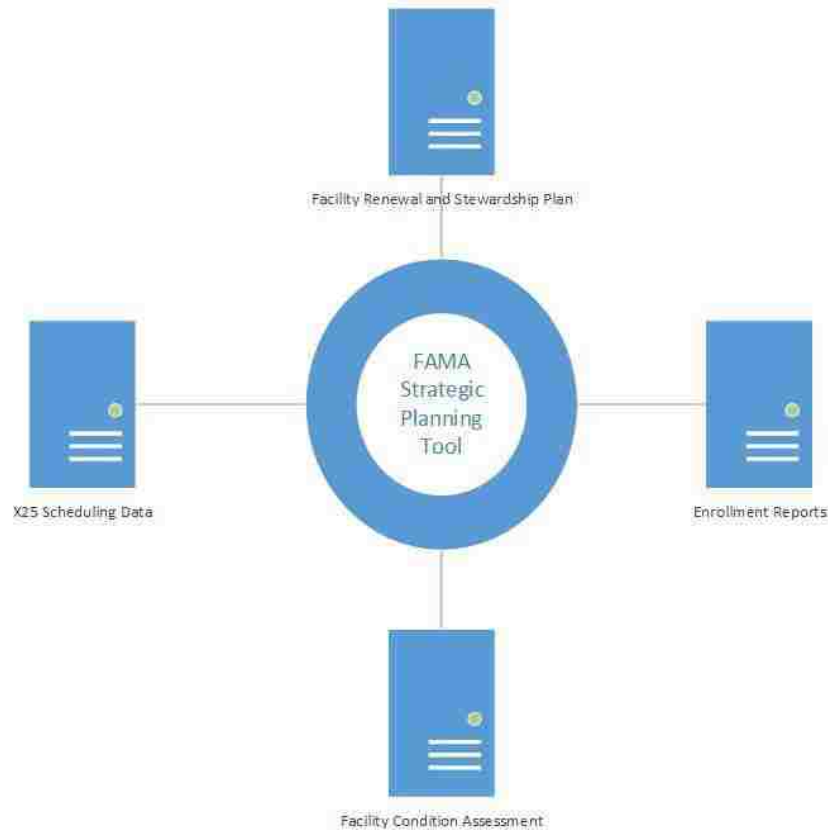


Figure 5.1 Data Sources for Planning Tool

Four out of the five objectives were gathered from a third party software called X25, developed by CollegeNET, Inc. Exposure to the software, as well as its capabilities and understanding were conducted by the one of the associates in the Central Scheduling Office at the Registrar's, which is discussed in the next section.

## 5.1 Central Scheduling Procedures

Jean E. Mitchell, Room Scheduling Coordinator at the Registrar's Office, provided invaluable information that allowed data gathering. She and her assistant are the only two people in the University that are responsible for class scheduling requirements and preferences. A general semester planning occurs typically the second month after the first day of classes of the previous semester. For Spring 2015, preliminary scheduling started as early as September. After the preliminary run is analyzed, each department in the University feeds their room scheduling requirements for next semester, into ISIS (Integrated Student Information System). Examples of some of the requirements that are provided:

- Class Frequency (MoWedFri, TuTh, MoWed, etc)
- Duration (50 minutes, 1 hour and 20 minutes, 2 hours, etc)
- Class Room Capacity (Max. number of students)

In addition to the class requirements, there are some specific requirements of each class, some examples include:

- Class Recording
- Projector
- Computers with specific software (AutoCad, Mathematica, etc.)

There is a deadline for filling out the requirements and scheduling preferences by department, which usually takes place a month and a half before the semester completion. After the deadline arrives, an additional analysis is conducted by Jean Mitchell, mainly to ensure that there are no scheduling conflicts that might arise as a consequence of similar class requirements. The scheduling plan is then sent to each department for approval, and notifications are sent allowing

each department to visualize their room allocation by the Registrar's Office. There is the high chance that the department's room allocation might not match what was originally requested, so possible alternatives are provided for the department's to choose. Additional changes are made to the scheduling plan based on these additional scenarios, which usually is finalized one month prior to the semester's completion. The final schedule is then sent to the Associate Vice Provost for Enrollment Service and Registrar, which approves the schedule for the following semester.

Optimization software is used to assist the Room Coordinator in her scheduling planning.

Powerful data analysis and optimization tools allow the scheduling tasks to be reliable and efficient. The optimization software used by the Room Coordinator is discussed in the following section.

## **5.2 College Net's X25, R25**

Most of the room's scheduling is done by a set of tools developed by CollegeNET, Inc. called the Series25<sup>®</sup>. "The all-in-one solution for scheduling" provides data gathering graphs that allow data interpretation to be easier and more reliable. It also provides mathematical optimization algorithms that generate scheduling plans in seconds.

The software series has two main components that are used by the Central scheduling associates in a daily basis:

1. Schedule25<sup>®</sup> Automated Classroom Scheduling: It is the optimization packet that processes all the department's scheduling requirements and preferences and prioritizes the allocation based on the software's defined attributes. For more information on how Schedule25 assesses mathematically prioritization, see the *Appendix*.

2. X25<sup>®</sup> Graphical Reporting and Analysis: It is the set of data analysis tools that provides useful visibility and trend recognition in scheduling and utilization. The software helps the user customize reports based on user defined preferences. Its exporting capabilities helped data manipulation into the development of the new tool much easier.

### **5.3 Utilization score measures and schedule preferences**

As mentioned in section 5.1, X25 was the data source for 4 out of the 5 objectives that were defined in the value hierarchy. In this section, illustrations that represent the data, as well as the score measures for each one of the applicable objectives are discussed. For more information on useful scheduling and utilization trends for the University of Arkansas, see the *Appendix* section.

Room utilization was the first objective to be analyzed. X25 returned 45 records of room utilization for applicable buildings on the timeframe analyzed. A snapshot was taken in the business week of September 8<sup>th</sup>, 2014. At this time, the early class dropping events after the first week of school had already taken place, so the snapshot that was taken would represent the consistent trend throughout the semester. The following illustration shows the different room utilization for the 45 applicable buildings:

**Room Supply vs. Actual Placement**  
 Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
 From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014

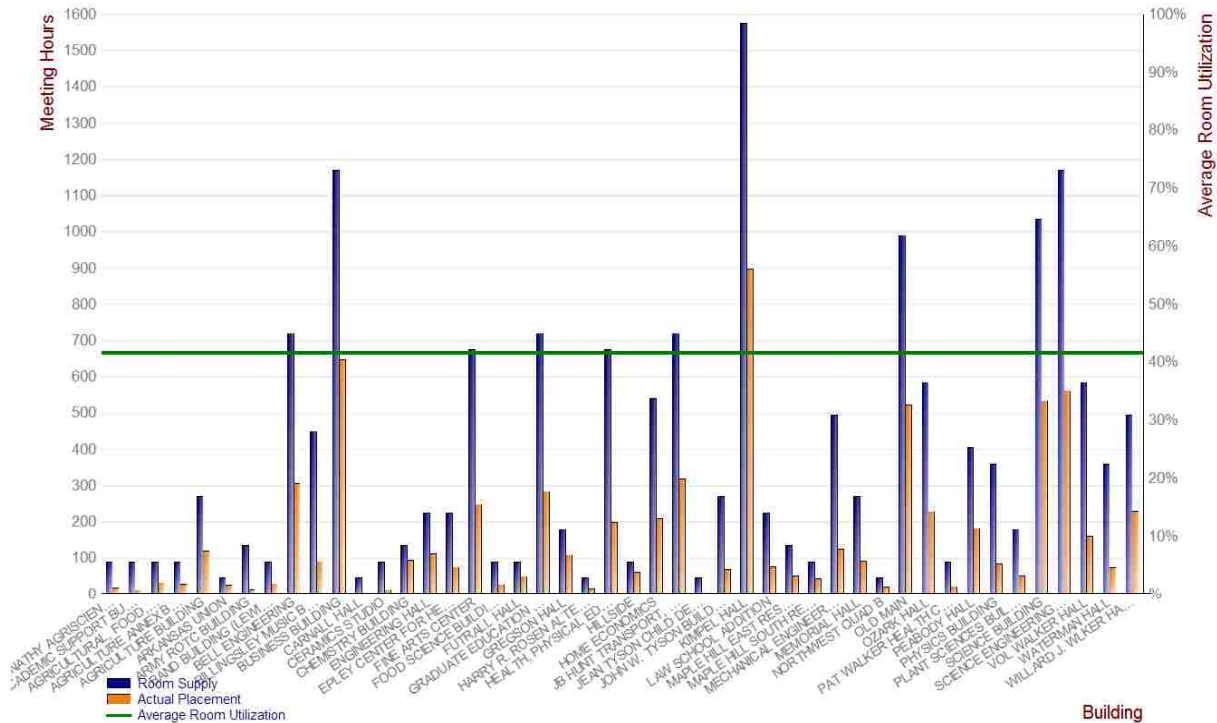


Figure 5.2 Room utilization per building

As we can see, Kimpel Hall shows the highest room utilization (55 %). The Business Building, Bell Engineering, the Science Building and the Science Engineering Building are other buildings that show utilization rates around 40%. The illustration does not include any class placements outside of the set Business day time frame (8:00 AM to 5:00 PM). The evening classes were excluded because they would incorrectly lower utilization rates. Additional observations about the objective are discussed in the *Discussion* section.

The second objective considered was seat utilization. The same buildings had data in the X25 system for seat utilization. The data distribution for the seat utilization data available in the system is shown below:

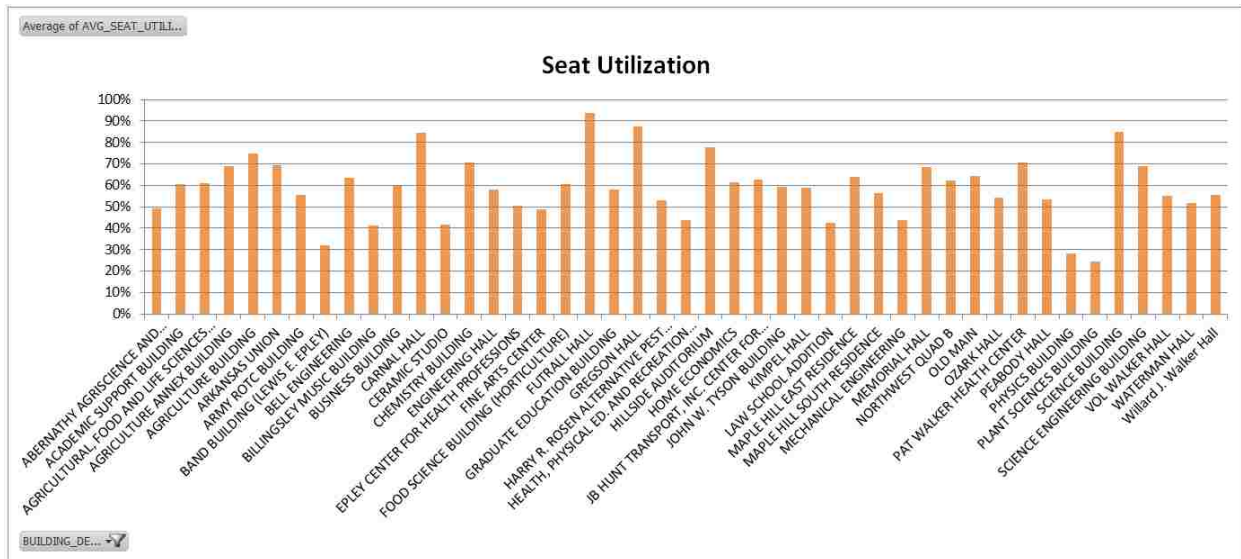


Figure 5.3 Seat utilization per building

As we can see, Futrall Hall is the building with highest seat utilization rate. There is a relation between room utilization and seat utilization. The Business building is a clear example. It has significant utilization rates for both objectives. This is not always the case. Some alternatives actually show an opposite direction. As an example, we can see how Gregson Hall has a really low utilization rate throughout the day; however, the seat utilization when classes are occurring is significant. This allows the stakeholders to understand and maybe consider scheduling classes in different alternatives where room utilization rates are low. Additional discussion about the subject can be found in the *Discussion* section.

The third objective considered was the average number of meeting hours per room for each building. The following illustration shows the data distribution for each building:



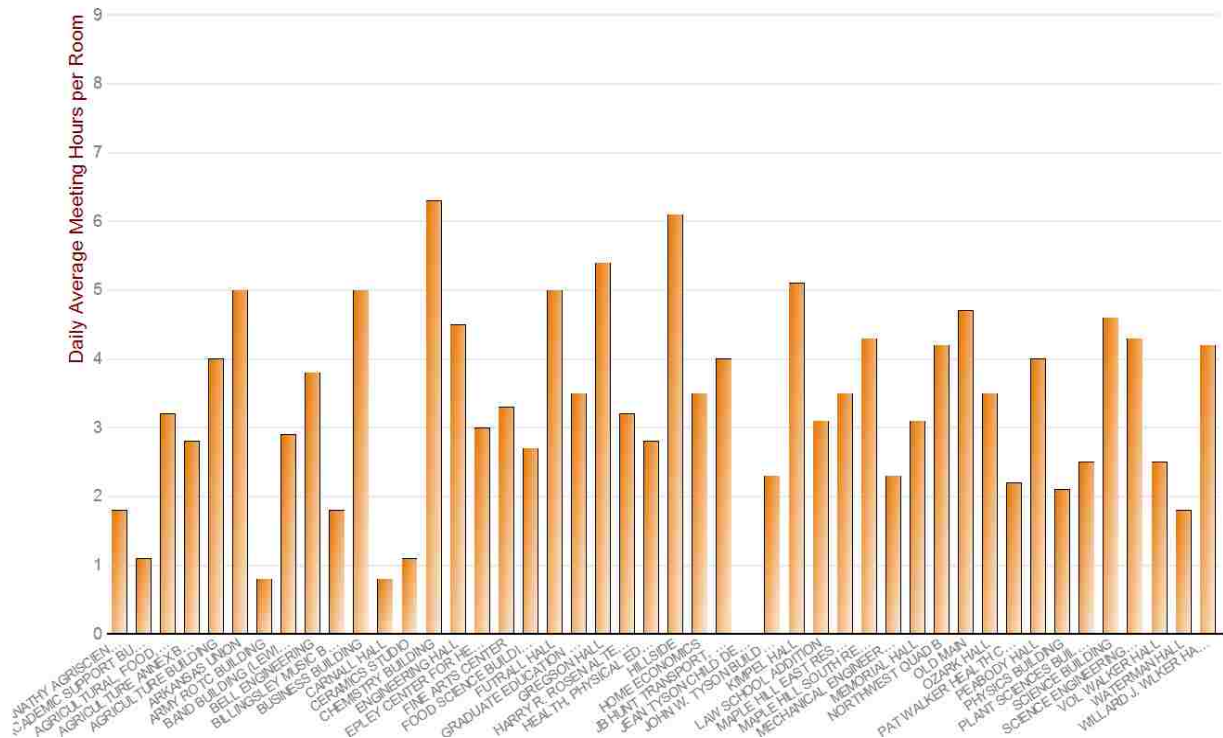


Figure 5.4 Average number of meeting hours per room

As the average meeting hours per room in a specific construction alternative is higher, a higher demand for scheduling classes in the alternative will occur. The Chemistry provides the highest value for this objective. There are some alternatives such as the Jean Tyson Child Development Center which show a lack of scheduling. If we go back to the Room utilization per building figure, we can see how the building presents a low supply in meeting hours per week (around 50), however, none of those 50 meeting hours are scheduled at all. This scheduling inefficiency will cause low utilization rates for buildings with similar scheduling patterns, which lowers their utilization rates, and affecting their total value as a whole.

The last objective that was taken from X25 had to do with scheduling preferences. Whenever a room is scheduled, the system validates if all the requirements required by the class have been

met or not (see section 5.1.1 for additional information about requirements). Based on these requirements, the system will categorize the scheduling allocation into one of four different categories:

- Class preferences match room (Green): When a department's scheduling responsible fills out requirements and the Scheduler25 system allocates a room with all the requirements that were requested.
- Partial match of class preferences to room (Yellow): When a department's scheduling responsible fills out requirements and the Scheduler25 system allocates a room with some, but not all, of the requirements requested.
- Class placed did not get preferences (Red): When a department's scheduling responsible fills out requirements and the Scheduler25 system allocates a room with none of the requirements that were requested.
- Class placed no preferences (Gray): When a department's scheduling responsible fills out a scheduling request without any specific requirements. The Scheduler25 system allocates a room based on availability.

Whenever a scheduling allocation falls under the yellow or red category, the department who got the allocation can ask for a schedule modification. There might be the case where a room needs all of the requirements for the class to take place, like a computer lab with specific software.

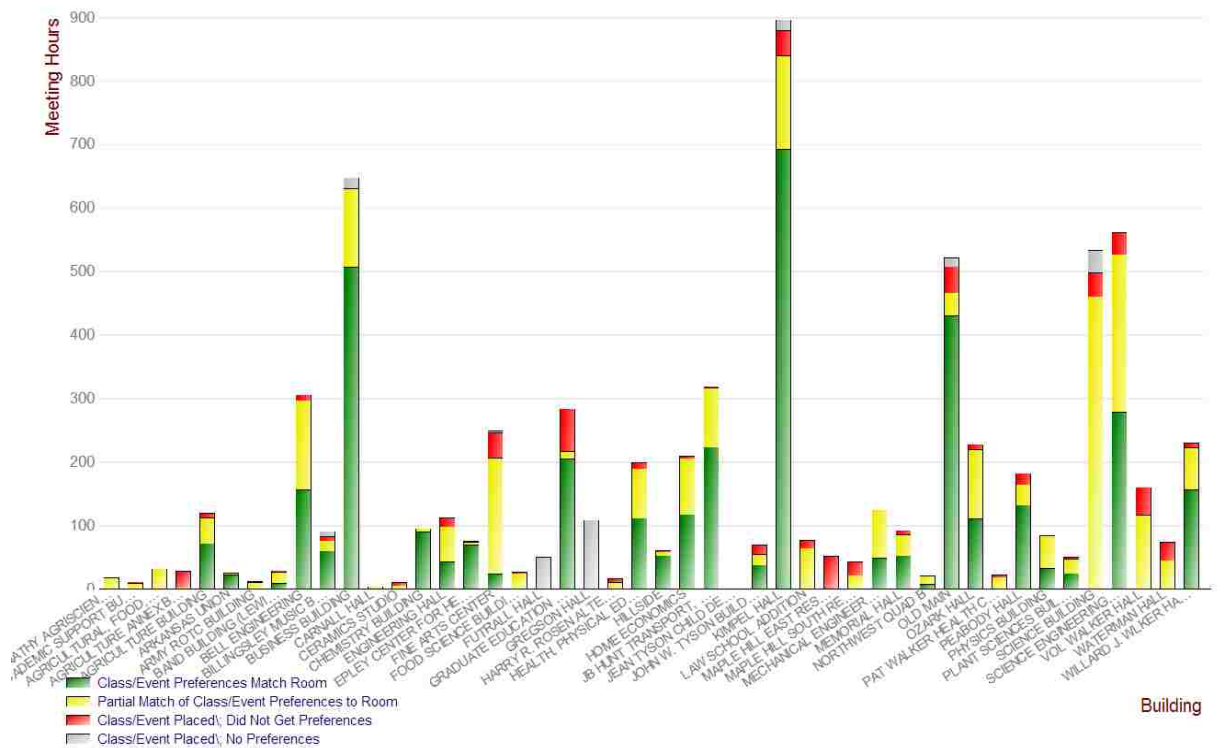
Without those requirements, the department will need to request a schedule modification. The scheduling modification, if feasible, has to be done outside the Scheduler25 system. The scheduling modification is a manual process as opposed to Scheduler25. Some examples that will require some manual intervention from central scheduling might be:

- A professor needs their classes to be close to each other because he had an accident and he is having trouble walking.
- Schedule25 has allocated two classes that are in really far away from each other, the majority of the freshman Industrial Engineer students are taking both classes, so it would be difficult for the students to get on time to their second class.

Again, 45 buildings have data under the X25 scheduling system. For modeling purposes, which is discussed in the next sections, the green scheduling preferences are only considered. One of the goals of this thesis/project is to understand and give value to alternatives outside of the partial preferences categories. Scheduling should be as efficient as possible, so the value measure is assessed as a percentage of the green category compared to the whole scheduling meetings hours for a specific building.

The following illustration shows the data distribution for the fourth objective:

**Class/Event Placement by Preferences**  
 Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
 From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014  
 Matching Campus Partitions, Features



Data Exported: Sep 30 2014

D3C5DF9491E9876F6423BA70839FF8DB

Generated by X25: Oct 04 2014 5:38 PM

Figure 5.5 Scheduling preferences by Building

Like some of the previous objectives that were discussed, Kimpel Hall is the alternative with highest meeting hours, however, the objective is assessed as a percentage of the green category as compared to the remaining meeting hours for that building, so even though Kimpel Hall is the building which highest meeting hours, the value measure for that building will be around 80% (700 meeting hours in the green category divided by a total of 900 meeting hours). Old Main, which has half of the meeting hours as Kimpel, has a higher scheduling percentage (around 85%, 440 meeting hours divided by 520 meeting hours). The Jean Tyson Child Development Center is an alternative that shows no value for scheduling preferences, because no class has been scheduled in that specific building.

Each one of the objectives discussed earlier will have a value function that defines how the value measures will assess value to a specific alternative.

The data source for the last objective, sustainability, is discussed in the next section.

#### **5.4 Facility Condition Assessment Database**

The Facility Condition Assessment is a Microsoft Access database that contains sustainability measurements for all buildings at the University of Arkansas. FAMA prepared an initial estimate in 2003 by conducting a facilities condition assessment of capital assets in order to accumulate data to develop the facility renewal and stewardship plan. The Facility Condition Index (FCI) is a value measure that was defined to indicate building deficiencies. It assesses the replacement value for each construction. If the FCI is 0, then it means that the building is brand new and there that there is no replacement value. If the FCI is 1, then the replacement value equals to the monetary value of the construction. A construction alternative can have an FCI of more than 1. As an example, a FCI level of 2 means that an investment of double the total value of the construction will be needed in order to replace it to brand new conditions. In order to determine the FCI level for each building, audits take place that evaluate if there are any construction deficiencies or any depreciation that should be considered in the assessment. Depending on the number of significant building observations that the auditors make, an FCI value is determined. The buildings are then categorized by rankings. The following table illustrates the different ranking according to the FCI level each building has:

<b>FCI Level</b>	<b>FCI Rank</b>
0 to 0.29999	A
0.3 to 0.5999	B
0.6 to 0.7999	C
0.8 – 0.9999	D
1 or greater	U

Figure 5.6 FCI levels and FCI ranks

The FCI Rank of “A” belongs to the buildings that have recently been constructed or that they have had a great maintenance history. Ranking B belongs to the middle aged constructions that have some deficiencies, but still have that overall new construction appearance. There might be some minor repairs that are increasing the FCI level, but the core structure is still in good shape. Ranking C refers to those buildings which have already have decades of operations, as well as some significant repairs that should be made to keep the building’s educational areas functional. These buildings are usually the ones where we see most student traffic, or the ones that have been built long time ago and their replacement value has increased over the years. Ranking U are those buildings whose replacement value exceeds the total cost of the construction, or special buildings such as the electrical Substation in Dickson Street. In the latter case, these buildings cannot be assessed with FCI levels because they serve a special purpose for the University of Arkansas. They are not E&G (Education and General) buildings where classes can be scheduled, therefore, they reside outside of the thesis’ scope. Buildings that fall under the U rankings are given a value on the sustainability function of 0. The more efficient and well maintained a building is, the more attractive it will be in a value standpoint. Something important to mention is that the FCI rank for a specific building can also improve. Assuming that the decision makers approve a renewal project for a specific building, the FCI level for that specific building will improve, since they are allocating resources to fix part of the building deficiencies. A total renewal will even bring the FCI level of the building back to 0. The following illustration shows an example of the FCA database output for Kimpel Hall in 2005:



## Facility Condition Assessment Database

View / Edit Bldg Detail | Run Reports | Activity Log | Miscellaneous...

Building Code:

FCI Rank	Historical	Address	Built	Age	Cost	Sq Ft	Rep Value
2010 C	<input type="checkbox"/>	280 McIlroy Ave.	1973	41	\$11,070,825	130,245	\$8,065,421

Building Type:  Zone:  Audit Team:  Famis Num:  Renovation Date:  Renovation Type:

Comments | Critical Outcome Scores | Deficiencies

SurveyYear	DescCode	DescName	MEPDesc	ArchDesc
2005 A		Substructure		Solid with no evidence of settling or major cra
2005 B		Shell		Solid and well-built requiring new thermopane
2005 C		Interiors		Standard and acceptable for the current use,
2005 D		Services	Most terminal equipment has reached f	
2005 D		Services	Fire hose cabinets are 2-1/2" Class I.	
2005 F		Spec Const & Demo		Typical classroom and standard toiletroom ap
2005 G		Sitework		Standard for this type of a project-some pavin

Please note: if critical outcome score data is altered, please click on recalc button to recalculate score summary score data.

Figure 5.7 Facility Condition Assessment Example (Kimpel Hall)

As we can see, Kimpel Hall is a 41 year old building. It is an educational building that has the most student traffic and meeting hours on campus, so it is understandable that the building will go through an accelerated depreciation process. Its replacement value is more than 70% of the initial cost of Kimpel's construction (adjusted to inflation). One of the auditors' observations was that most of the terminal equipment has reached feasible life span. The equipment and systems in the building should be modernized for continued efficiency.

### 5.5 Enrollment Reports

The office of institutional research at the University of Arkansas provides detailed enrollment data per semester. Even though enrollment is not a factor that assesses value for a construction project, it definitely influences how financial resources are going to be allocated to the possible alternatives. The student enrollment is a key factor for measuring the budget available for the alternatives. The way the budget is calculated is discussed in section 5.5. The enrollment report

is released on the 11<sup>th</sup> day after the beginning of each semester. This allows capturing any additional enrollment in the first week of class, as well as students dropping during the first week. The students do not get charged any fee if they decide to drop out the first week, so this is quite a common circumstance. An example of the latest enrollment report for Fall 2014 can be found in the *Appendix* section. Unprecedented student enrollment increase is one of the reasons why the thesis project was initiated. The FAMA stakeholders wanted additional visibility on the student enrollment for the next years, so it was necessary to review the historical enrollment data to make a forecast for future years. The mathematical equation used to calculate the future student enrollment is discussed in section 6.4.

Now that the different data sources have been identified, the relationship and interaction between the data sources, as well as the software development and mathematical modeling are discussed in the next chapter.



## Chapter 6: FAMA Strategic Integrated Planning Tool

After several conversations with the FAMA stakeholders, a decision was made for the model to be developed in Microsoft Excel<sup>®</sup> for several reasons:

1. Spreadsheets are many times the best choice whenever there are some quantitative values that have to be shown. Executive summaries for the decision makers, as well as detailed analysis can be contained in a single excel file.
2. The software is familiar by all of the stakeholders in the FAMA team: Being ultimately the customers, it was essential for them to use a computer based software that was already familiar. Microsoft Access was another feasible alternative; however, some of the stakeholders were not familiar with it, which would've required training in the software.
3. It allows easy editing and updating with the right documentation process: The development included Excel functions such as VLOOKUP, SUM, or FORECAST that are already familiar by the stakeholders. This allows knowing the data sources relationships, as well as keeping the tables where the score measures are contained with current information.
4. The Solver function is the optimization engine included in Microsoft Excel can find the best possible alternatives for the available budget.

The model's parameters are discussed in the next section.

## 6.1 Model Parameters

The computer based Excel model has been labeled as the “FAMA Integrated Strategic Planning Tool”. Its main objective is to allow integration of different sources of data into one single model that would allow to strategically guide construction decisions based on user defined constraints.

The following illustration shows the tool’s main menu:

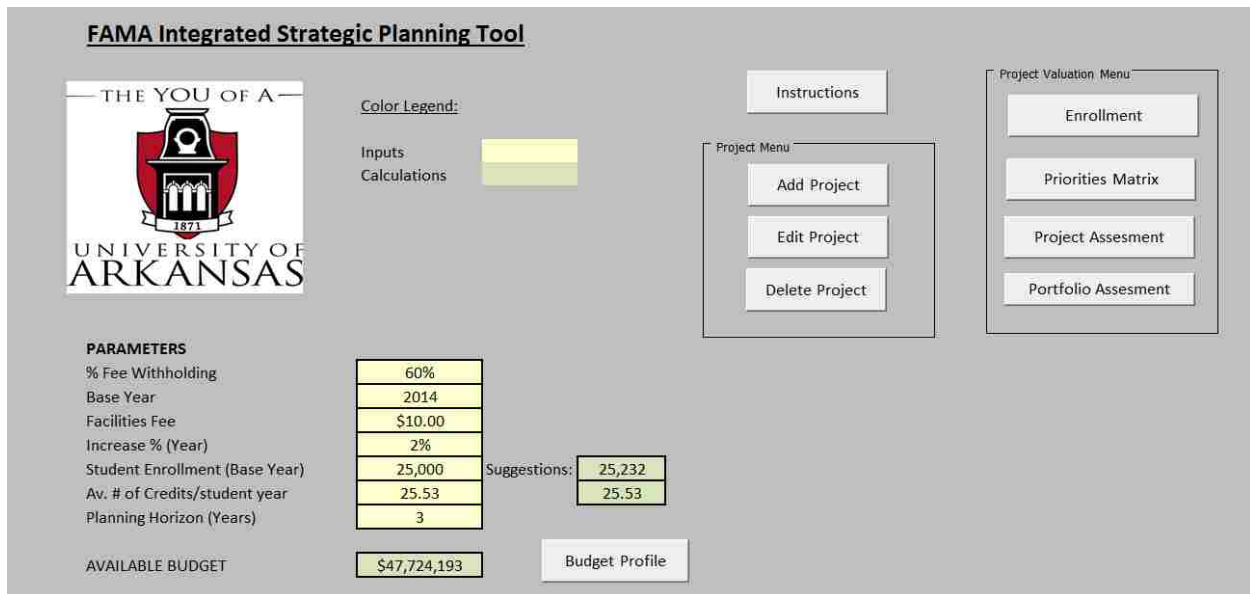


Figure 6.1 FAMA Integrated Strategic Planning Tool Main Menu

Based on the illustration, the components of the model are divided as following:

- Parameters
- Budget Profile
- Projects
- Priorities (Swing Weights)
- Project Assessment
- Portfolio Assessment

Each one of the model components will be discussed in the next sections.

## 6.2 Projects

The Project's Menu allows the user to define the alternatives to be evaluated by the decision makers. Each project will be defined by the followed parameters:

- **Project ID:** It is unique number generated from the tool that allows identifying the project in the source data tables which will be discussed later.
- **Building Code:** It is the 4 letter acronym by which the project is identified. Whenever a Building Code is defined in the project information, the tool will gather historical information from that building in order to assess value (Explained later in section 5.2.7).
- **Project Description:** Is it the project description that allows the user to identify a name to the specific construction building.
- **Category:** It is the field that defines whether the construction will be New or a Renovation. Whenever a New project is evaluated, there won't be historical information for all of the 5 defined objectives in the value hierarchy, therefore, the way the model calculate the score measures is different. The two alternatives are discussed more in depth in section 5.2.7.
- **Year Built (optional):** Is it an informational field that allows the user to understand how many years have the construction been depreciated. It does not have any influence in a modeling stand point.
- **GSF (optional):** It is the Gross Square Feet planned for the construction alternative. This allows the user to understand the extent of the construction's planning.

The final two parameters define the project cost. It is broken down into two different categories. The Facility Renewal and Stewardship Plan have the same two different categories for each construction alternative:

1. Private Funding: It refers to the portion of the total project cost that comes from private funds, grants, gifts or any other private source that might help fund the project.
2. Facility Fee Funding: It refers to the portion of the total project cost that will come from the facility fee funding. The way the facility fee funding is calculated for the available budget as a whole will be discussed in the *Budget Availability* section 5.2.4.

The Total Project Cost will be a calculated field is the sum of both funding parts.

The user has the ability to enter as many construction alternatives as he/she desires in the tool. They are stored in a table that will alter be retrieved for the project assessment. The user also has the possibility of editing any information that has already been stored in the system. After the information is updated, it will be saved in the data source that contains the project information. Finally, the user has the ability to delete any project that should no longer be considered in the project and portfolio assessment. The following figure illustrates a snapshot of the Project Information Edit Menu that shows an example for Project number 3 in the Stewardship Plan:

Select Project ID:

**PROJECT INFORMATION**

<b>Project ID:</b>	3
<b>Building Code:</b>	FNAR
<b>Project Description:</b>	FINE ARTS CENTER (WHOLE BUILDING)
<b>Category:</b>	RENOVATION
<b>Year Built:</b>	1951
<b>GSF:</b>	116,915
<b>Private Funding:</b>	\$10,000,000
<b>Facility Fee Funding:</b>	\$10,820,000
<b>Total Project Cost:</b>	\$20,820,000

Figure 6.2 Project Menu

Now that we have an understanding on how each project is defined, some parameters have to be defined in order to calculate the available budget as well as the time horizon, which are discussed in the next section.

### 6.3 Parameters

The following figure shows the different parameters that need to be defined for calculating part of the total available budget, which is discussed in the next section:

PARAMETERS	
% Fee Withholding	60%
Base Year	2015
Facilities Fee	\$10.00
Increase % (Year)	1%
Student Enrollment (Base Year)	26,237
Av. # of Credits/student year	25.53
Planning Horizon (Years)	3
AVAILABLE BUDGET	\$47,985,910

Suggestions:	26,288
	25.73

Budget Profile
----------------

Figure 6.3 Tool Parameters

- % Fee Withholding: It is a fixed percentage that is used to account for how much of the facilities fee portion of the budget goes to previous debts. Additional discussion is presented in Section 5.2.4.
- Base Year: It refers to the year for which the planning horizon begins. This variable is important as it has a direct relation with the number of students expected to be enrolled for the defined base year.
- Facilities Fee: The Facilities Fee is charged in a per credit basis to each student in the University of Arkansas. It is one ways Facilities Management obtains funding for their construction projects. It is necessary to understand the background of how this parameter has changed over the years. The facility fee started as \$ 2.00 per credit hour in FY2009

(2008-2009). Due to unprecedented student enrollment, the FAMA stakeholders pushed for a 5 year plan facilities fee increase to the Board of Trustees. One of the arguments presented to the Board was the necessity of additional funding to cover the increase in enrollment that the University was going to expect. The Board of Trustees approved a \$ 2.00 per year increase for a 5 year period (2008-2013). This is one of the several reasons why the University has had a construction drive in the past years. The increase has finally established at \$10.00, and has not moved for the next academic calendar. The FAMA stakeholders have worked hard this year in order to establish a new proposal to increase the fee. The approval is a complex process that needs to be completely justified, as it affects the overall tuition per student charged. There are restrictions on the fee increases by the University and the State of Arkansas. The preliminary proposal aims at approving a fixed percentage increase for the next 10 years. The FAMA stakeholders have not defined a fixed percentage of increase in the proposal, however, it was important to consider this increase in the modeling as one of the variables.

- Increase %: As discussed previously, the increase percentage variable reflects the facility fee increase in a per year basis. It will be applied as a percentage increase of the previous year of the budget series, which will be explained in section 6.4
- Student Enrollment (Base Year): This field indicates the expected student enrollment for the base year. The tool has a suggestion for the expected enrollment based on the selected based year in case the user is not sure about the value of enrollment in future years. The way the suggestion calculates the suggestion is based on a linear regression on the last 8 semesters. The following chart illustrates the student enrollment regression as well as the equation used to calculate the enrollment in the future years:

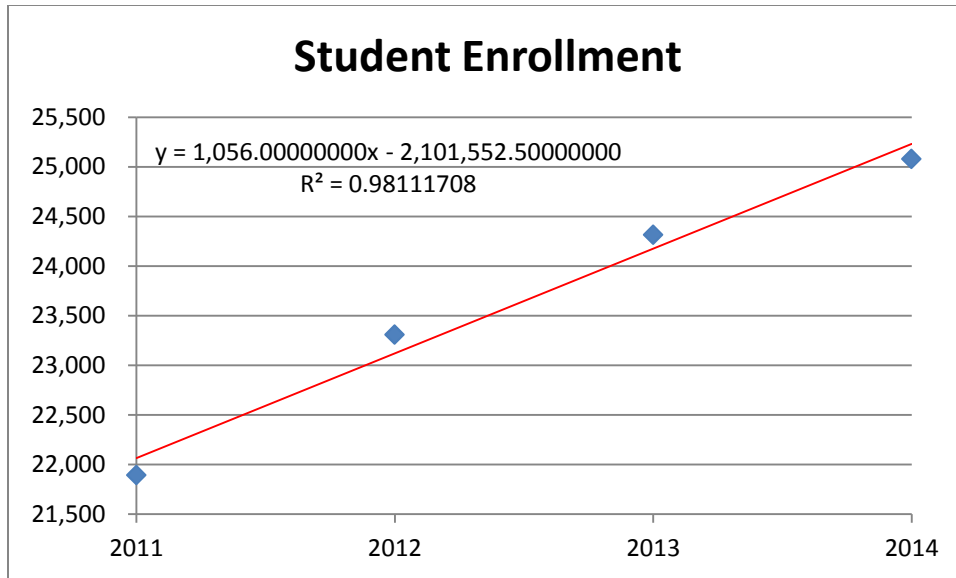


Figure 6.4 Student Enrollment Regression

- Av. # of credits/student year: Since the facilities fee is assessed in a per credit basis, it is necessary to understand an average of the number of credit hours each year. In a similar way as the student enrollment data, a suggestion is included in the tool based on a linear regression that recommends the user a suggested value based on historical data. Based on the differences between undergraduate and graduate number of credits, it was necessary to under an average as a whole. Typically undergraduate students take around 14-15 credits a semester, while graduate students take fewer credit hours (around 12 credit hours) The following figure illustrates the regression used for the suggestion:

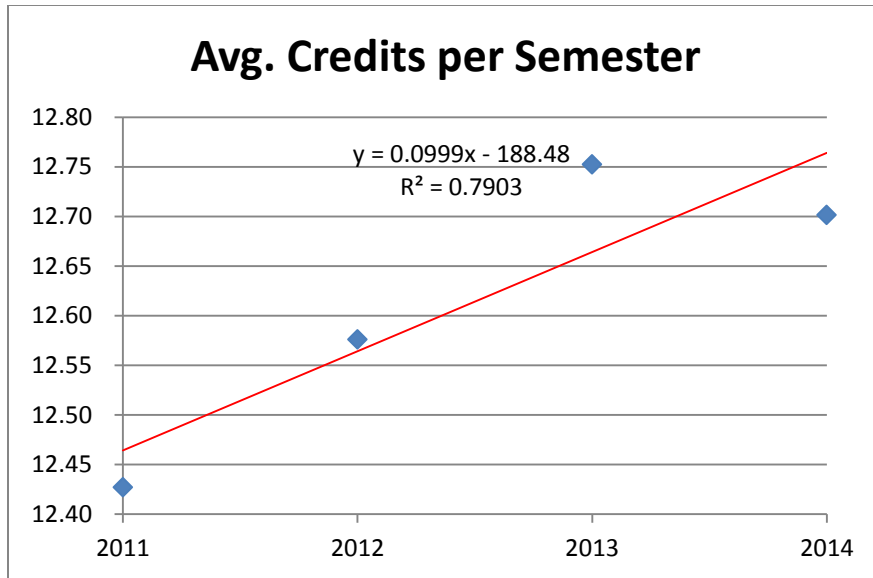


Figure 6.5 Average Number of Credit Hours Regression

- **Planning horizon:** This field refers to the number of years the alternatives will be budgeted for. Each year, different budget sources will be defined in the Budget Profile (discussed in the next section), so the planning horizon defines the projects' timeframe. As an example. Having a base year of 2015 with a planning horizon of 3 years, means that the projects will be considered for the 2015-2017 range. Each year will have its defined budget, but the portfolio allocation will be based on that 3 year total available budget.

Now that all the different parameters that drive the budget have been defined, the different parts of how the budget is constructed can be discussed. The parameters usually drive just one out of six different categories in the total available budget for the planning horizon, which are discussed in the following section.



## 6.4 Budget Availability

The available budget is the sum of 6 different components defined by the FAMA stakeholders.

These six components will have a different value for each year in the planning horizon. Scott

Turley, the utility operations & maintenance Director, is the one that gathers this information

each year. He has created an excel template that allows visibility and easy data update as new

budget components arise. A snapshot of the Excel Template is shown in the *Appendix* section.

The following figure illustrates how each one of the funding sources is defined in the computer based tool:

Main Menu		Charts		Budget Profile (per thousands)				
Year	TOTAL	General Operating Budget	Capital Lease (ESPCs)	Facility Fee (Annual Investments)	Facility Fee (Bonds from Debt Service)	Grants / Governmental / Endowments	Private Gifts	
	\$47,986	\$11,478	\$0	\$8,458	\$12,000	\$1,050	\$15,000	
2015	\$11,576	\$3,547	\$0	\$2,679	\$0	\$350	\$5,000	
2016	\$23,833	\$3,663	\$0	\$2,820	\$12,000	\$350	\$5,000	
2017	\$12,577	\$4,268	\$0	\$2,958	\$0	\$350	\$5,000	

Figure 6.6 Budget Definition in the Tool

The categories are described as following:

1. **General Operating Budget:** This category refers to all the operating budget available each year. Some examples are, and not limited to: Renewals (Lvl 3 Planned Renewal, Delta T Capital Renewal, Mullins Creek Restoration, City of Fayetteville Match, between others), Auxiliary funding (Signage & Way Finding, ADA Compliance Review, etc.) and Energy Savings Performance Contracts net Savings (Utility Savings less Lease Payment).
2. **Capital Lease (ESPCs):** This category refers to the generated available capital from energy savings. Based on current performance contracts established in 2009, there are three different contracts that provide funding to the total budget:
  - a) Poultry Science – ESPC I
  - b) Campus Wide Improvements – ESPC III (a)
  - c) Campus Wide Improvements – ESPC III (b)

3. Facility Fee (Annual Investments): The category of the total budget that is calculated based on the parameters defined in the Strategic Tool's Main Menu. The facility fee per year over the planning horizon is defined the following geometric series assuming the following variables:

BY = Base year  
 CH = Average credit hour per student year  
 FF = Facilities fee determined by FAMA  
 PH = Planning horizon  
 FI = Fee increase percentage  
 SE<sub>t</sub> = Student Enrollment for year t

The available budget for year *t* will be defined by the following equation:

$$Facilities\ Fee\ Budget(t) = CH * \sum_{n=0}^{BY+PH-t-1} FF * (1 + FI)^n * SE_{(BY+n)}$$

Where:

SE<sub>t</sub> is equal to the base year enrollment in case year *t* is the base year, or the following linear regression otherwise:

$$SE_t = 1056 * t - 2101552.5$$

We calculate the Facilities fee budget for year 2015 assuming the following data as an example:

BY = 2014  
 CH = 25.53  
 FF = \$10.00  
 PH = 3  
 FI = 2%  
 SE<sub>BY</sub> = 25,000

$$\begin{aligned}
 Facilities\ Fee\ Budget(2015) &= 25.53 * \sum_{n=0}^{2014+3-2015-1} 10 * (1 + 2\%)^n * SE_{(BY+n)} \\
 &= 25.53 * 10 * (1 + 2\%)^0 * SE_{2014} + 25.53 * 10 * (1 + 2\%)^1 * SE_{2015} \\
 &= 25.53 * 10 * (1.02)^0 * 25,000 + 25.53 * 10 * (1.02)^1 * (1056 * 2015 - 2101552.5)
 \end{aligned}$$

$$Facilities\ Fee\ Budget(2015) = \$ 6,845,422.73$$

The previous facilities budget equation determined the maximum available funding for each given year. In reality, not all of this maximum funding value will be available on that given year. FAMA stakeholders have pointed out that a fraction of this total maximum is allocated to cover previous bond debts. It is applied in a per year basis to each one of the Facilities Fee Budget years over the planning horizon the following way:

$$\text{True Facilities fee (t)} = (1 - \% \text{ Withholding}) * \text{Facilities Fee Budget (t)}$$

4. Facility Fee (Bonds from Debt Service): It is the portion of the budget that accounts for bond issues in a given year. The FAMA stakeholders have mentioned that whenever the percentage of % withholding on a given year is high, the University tends to issue bonds to gain some funding. As long as the University has enough money in order to pay the previous bond interests, the cycle can still go on. Usually the decision to issue a bond is a process that does not have any specific trend, but it is still a significant portion of the available budget that should be considered.
5. Grants/Governmental/Endowments: The category of the total budget that refers to any grants that or state match funding that is allocated to construction projects. The Arkansas Natural and Cultural Resources Council is one of the institutions that offer this type of funding.
6. Private Gifts: It refers to any private funding coming from affiliated institutions, alumni, city donors, etc. Usually these private gifts involve naming opportunities as an appreciation of the financial contributions.

The six different budget categories are aggregated into a single source of available budget, becoming the main constraint in the model. The total project cost for all of the selected

alternatives should not exceed this available budget. The way this constraint is considered in the optimization algorithm is discussed in section 6.7.

The previous figure 6.6 shows the budget allocation for the Facility Renewal and Stewardship Plan 3 year planning horizon. Based on figure 6.3 parameters, the total available budget for the plan is \$ 47,985,910.

The tool has built in graphs that allow the user to understand how much each one of the budget categories represents out of the total budget. As the parameters are changed, the graphs are automatically updated. See *Appendix* for detailed budget breakdown.

### **6.5 Swing Weight Matrix**

Now that the budget constraint has been defined, it is necessary to discuss the ways the FAMA stakeholders can define the value functions that provide value to the alternatives. Going back to the value hierarchy defined in figure 4.4, there are five different objectives, each one with its own value measure, that provides value to the alternative. The first three objectives were aggregated as part of the “Improve building utilization” function. Room utilization, seat utilization, and average events per room are the three value measures that define this function. The sustainability portion of the project assessment is defined by the “Achieve sustainability” function, which is measured by the % Match Preference. Finally, the Scheduling preferences function is defined by the % of Match preference as discussed in the previous section.

The following figure illustrates the Value hierarchy and priorities menu, where the stakeholders define the value function shapes, as well as their weight percentage:

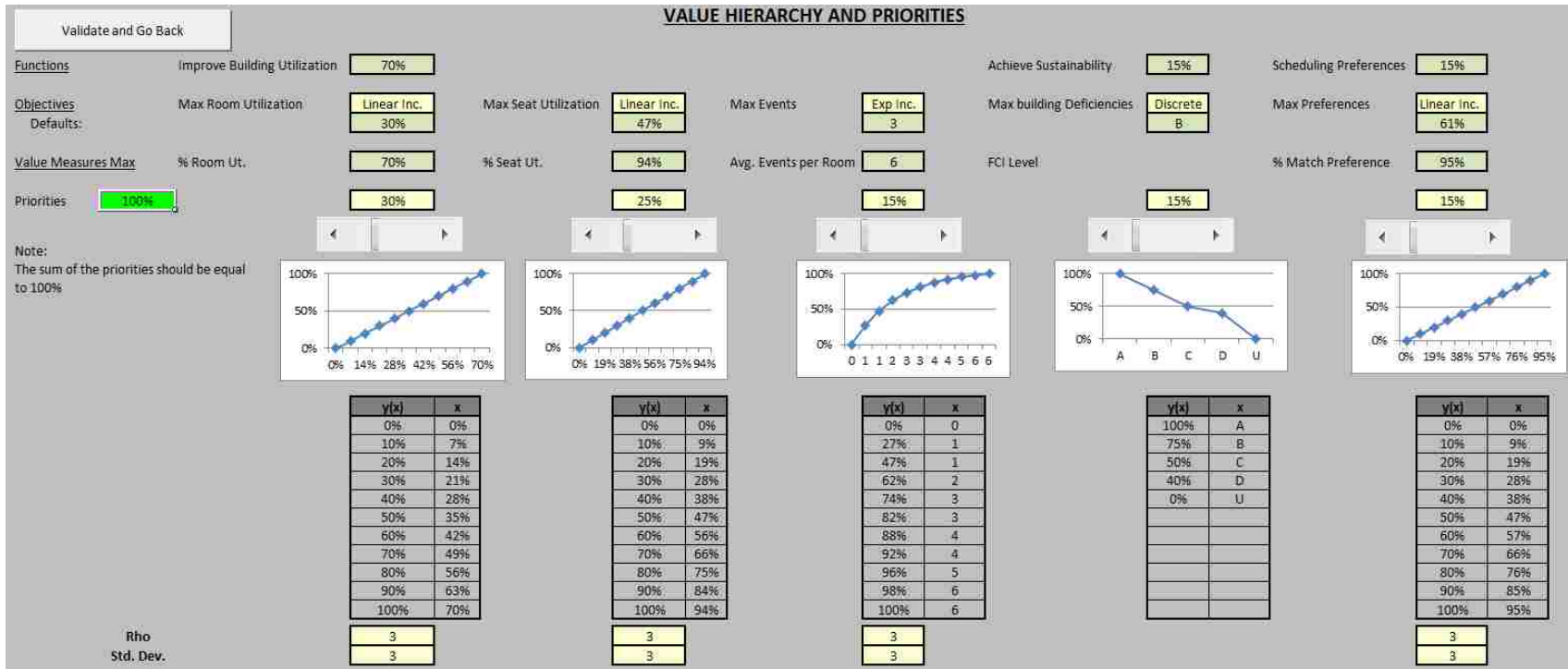


Figure 6.7 Value hierarchy and priorities menu

The stakeholders have the ability to choose between six different function shapes that determine how the returns to scale for a given value measure is assessed. The shapes included in the computer based tool were defined based on several conversations with the FAMA stakeholders, as well as looking at most common function shapes. Before providing a brief description for each one of the function shapes, it is important to understand how the range of the function shape is defined. The function shape defines the impact of “swinging” the value measure from a worst to best level (range). Typically this is a fixed range like 0 to 100 or 0 to 10. The problem with a fixed range lies in the fact that value can be underestimated for an objective if the range definition is too broad. If we take room utilization as an example, there might be the case that all of the alternatives have a really low utilization rate, let say 30%. So if we define 0-100% as the range where the value measures swings, the best alternative will just have 30% of that objective. Defining 0 - 100% would not be realistic, because in reality, a construction alternative will never reach 100% of room utilization. The reason analysts usually take this approach lies in the fact that the value measures for all the alternatives should be included in the defined range. Utilization rates can increase throughout the years, so analysts usually define these broad ranges to consider possible value measure increases in the future.

This thesis defines the range in a dynamic way. Maximum values for each one of the five objectives can be defined, so the value measures will “swing” from 0 to the defined upper boundary. If we look at room utilization as an example from the previous figure, the defined upper boundary is 70%, so the value measures for that objectives will swing between 0 and 70%. The user has the ability to change the upper boundary as desired. The tool has built in functions that provide upper boundary suggestions for each one of the objectives except sustainability, which is a discrete function that is discussed in the following page. The function takes the

maximum value measure for the alternatives loaded in the system. The user has the ability to change the upper boundary if the suggestion does not match the user's preferences.

Going back to the project definition in section 6.2, there will be projects that are prospective new constructions, so we unfortunately won't have any historical information for any of the five objectives defined, for this case, "Defaults" values are defined in order to assign them to new construction projects. In the room utilization example, the default value is 30%, so if the project category is defined as new, that default value of 30% will be considered in the project assessment.

The user can pick from 5 different shapes that assess return to scale for a given objective the following way:

1. Linear Increasing: Taking room utilization as an example, as room utilization for a given alternative increases, the value for that objective will increase linearly. The value measure will swing from 0 to the defined upper boundary. The shape is defined by a linear function between two points (0, 0) and (UB,1).
2. Linear Decreasing: In an opposite way as the previous shape, as the level increases, the value for the objective will decrease. The shape is also defined by a line between two points, (0,1) and (UB,0).
3. Exponential Increasing: The shape is defined by the following exponential function:

LB = Lower Bound

UB =Upper Bound

Rho = variable that defines the slope of the exponential function

$$f(x, LB, UB, Rho) = \frac{1 - e^{\frac{-x+LB}{Rho}}}{1 - e^{\frac{-UB+LB}{Rho}}}$$

After several conversations with the stakeholders, the slope of the exponential function would have to be an intermediate between a linear and a completely sloped exponential function. A rho of 3 was considered as appropriate for exponential functions.

4. Exponential Decreasing: Using the same example, as the room utilization increases for a given alternative, the value for the objective will decrease. The function that defines the exponential function in this case is slightly different:

$$f(x, LB, UB, Rho) = \frac{1 - e^{\frac{-UB+x}{Rho}}}{1 - e^{\frac{-UB+LB}{Rho}}}$$

For both exponential functions, the user will be able to define the rho he/she wants to use in case the shape defined for a specific objective is exponential.

5. Normal (customized): A function familiar to the normal function was defined in order to account for a shape that would return the highest return to scale in the middle of the range. The equation that describes this shape is the following:

$$f(x, \mu, \sigma) = 2 \int_{-\infty}^x \frac{1}{\sqrt{2\pi}\sigma} e^{-\left(\frac{x-\mu}{2\sigma^2}\right)}$$

Where:

$\mu = UB/2$  and  $\sigma = UB/slope\_coefficient$

The slope coefficient is a variable in the tool that allows the user to define the slope of the normal in a similar way rho does for the exponential function. As the value of the slope gets bigger, the values that are into the side of the mean will decrease.



There is an additional discrete, which is sustainability. Since the value measure for this objective is defined by five possible ranks, a discrete function had to be defined that would determine the returns to scale for a specific score (ranking). The discrete function used was:

$$f(x) = \begin{cases} 1, & x = A \\ 0.75, & x = B \\ 0.50, & x = C \\ 0.40, & x = D \\ 0, & x = U \end{cases}$$

Based on the different shape definitions, as well as the flexibility of adjusting certain attributes inside a function, the stakeholders have the ability to define how each objective will assess value to the project.

In reality, each measure will not have the same importance as others. The FAMA stakeholders have mentioned how sustainability, even though being a currently recent trend, it still does not account significant importance when evaluating decisions, therefore, the importance of sustainability should be less than the utilization objectives.

In order to account for this importance of each objective, “priorities” or weights are defined for each objective. The total value of a project will be the weighted average:

$$v(x) = \sum_{i=1}^n w_i v_i(x_i)$$

$$\sum_{i=1}^n w_i = 1$$

Where:

- $v(x)$  = value for alternative  $x$
- $w_i$  = weight for objective  $i$
- $n$  = number of objectives
- $x_i$  = score for value measure  $i$
- $v_i(x_i)$  = returns to scale for value measure  $i$

The constraint that defines the weighted average states that the sum of the priorities should equal to 1.

Based on conversations with stakeholders, the following weights, shapes, defaults, Max upper boundaries, and slope variables were defined for each one of the value measures:

Value Measure	Weight	Shape	Defaults	Upper Bound	Rho	Slope Coefficient
Max Room Utilization	30%	Linear Increasing	30%	70%	3	5
Max Seat Utilization	25%	Linear Increasing	47%	94%	3	5
Avg. Events per Room	15%	Exp. Increasing	3	6	3	5
FCI Level	15%	Discrete	B	N/A	3	5
% Match Preference	15%	Linear Increasing	61%	95%	3	5

Figure 6.8 Priorities Matrix Definition

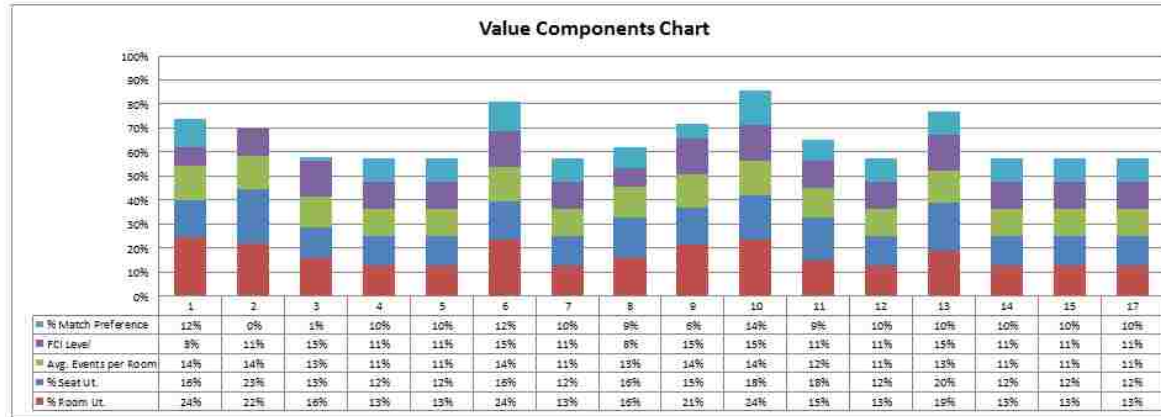
## 6.6 Project Assessment

The Project assessment takes place after the alternatives; budget and the priorities have been defined. The tool retrieves information from the X 25 and the Facilities Assessment Database stored in a table inside the tool. See *Appendix* for example.

The menu is divided into 2 different tables, the score measures table, and the values table. The process is executed as soon as the “1. Construct Tables” button is pressed. The first table stores the scores for each value measure that is retrieved from the Data Sources Table, which contains X25 and FCA data. The second table stores values that are calculated from a built in function, giving the appropriate value to each objective based on the function shape and weight defined in the Priorities Menu. As we can see in the figure, each one of the shape are consistent with how they were defined previously on the Priorities menu. The built in function evaluates the shape of the function, as well the weight that has been defined for that particular objective, then, it gives an appropriate value based on the score stored in the Score Measures Table. The figure in the

next page shows a snapshot of the project assessment menu after the process has been completed. The process retrieves information from the Data Source table and populates in the Values Measures table. Depending on the project category (new or renovation), the data will be retrieved in different ways. If renovation, the data will be retrieved based on the project's building code, there are currently 45 different buildings stored in the Data Sources table, so if there is historical data for that specific building, the process populates the Score measures table with historical data. If the project's category is new, or the building code is not found in the Data sources table, the score populated in the value measure table will be the default value defined in the priorities menu. Taking Kimpel hall as an example (busiest building on campus), we can see that the process retrieves 57% as its building utilization. It is a renovation project that has historical data, so the value is project specific in this case. Looking at project 16 as the other example, we can that its value retrieved by the process for the FCI level is B. Project 16 is a University entrance renewal project that does not have any utilization rates, so the default is retrieved.

Value Measures						
Project ID	Building Code	% Room Ut.	% Seat Ut.	Avg. Events per Room	FCI Level	% Match Preference
1	KIMP	57%	59%	5	C	77%
2	SCIE	52%	85%	5	B	0%
3	FNAR	37%	49%	3	A	9%
4	MULN	30%	47%	3	B	61%
5		30%	47%	3	B	61%
6	WCOB	55%	60%	5	A	78%
7		30%	47%	3	B	61%
8	HOEC	39%	62%	4	C	56%
9	ENGR	50%	58%	5	A	38%
10	AFKU	55%	69%	5	A	90%
11	MEMH	34%	69%	3	B	57%
12	MULN	30%	47%	3	B	61%
13	AGFI	44%	75%	4	A	80%
14	NAND	30%	47%	3	B	61%
15	GTWR	30%	47%	3	B	61%
16		30%	47%	3	B	61%



FUNCTION BEHAVIOR SWING WEIGHTS		Linear Inc. 30%	Linear Inc. 25%	Exp Inc. 15%	Discrete 15%	Linear Inc. 15%	TOTAL	COST
Project ID	Building Code	% Room Ut.	% Seat Ut.	Avg. Events per Room	FCI Level	% Match Preference		
1	KIMP	24%	16%	14%	8%	12%	74%	\$9,560,000
2	SCIE	22%	23%	14%	0%	0%	70%	\$4,950,000
3	FNAR	16%	13%	13%	15%	1%	58%	\$20,820,000
4	MULN	13%	12%	11%	11%	10%	57%	\$11,410,000
5		13%	12%	11%	11%	10%	57%	\$31,000,000
6	WCOB	24%	16%	14%	15%	12%	81%	\$20,000,000
7		13%	12%	11%	11%	10%	57%	\$32,000,000
8	HOEC	16%	16%	13%	8%	9%	62%	\$9,800,000
9	ENGR	21%	15%	14%	15%	6%	72%	\$19,580,000
10	AFKU	24%	18%	14%	15%	14%	86%	\$6,000,000
11	MEMH	15%	18%	12%	11%	9%	65%	\$16,850,000
12	MULN	13%	12%	11%	11%	10%	57%	\$15,440,000
13	AGFI	19%	20%	13%	15%	10%	77%	\$18,720,000
14	NAND	13%	12%	11%	11%	10%	57%	\$5,990,000
15	GTWR	13%	12%	11%	11%	10%	57%	\$8,000,000
16		13%	12%	11%	11%	10%	57%	\$2,000,000

Figure 6.9 Project Assessment Example

One of the problems about using the default value for projects that do not have historical data, is that we would be comparing the value of this project with proposed default value that are not real, they are simply suggestions that tool gives to the user based on the proposed default values the stakeholders have defined. If we look at figure 6.9, there are 6 projects out of the total 16 that have default values. In a project assessment standpoint, these projects will have the exact same value, which is not realistic. The decision hierarchy defined in section 4.5 establishes that only educational and general (E&G) construction projects will be considered. There are some projects in the stewardship plan that are not applicable to the decision framing, however, they were still included in the project assessment if the stakeholders desire to take a look these projects' value. The projects are excluded later in the portfolio assessment, which is part of the constraints definition in section 6.7.

In case the user is not comfortable with the score a specific project has been given under an objective, the user has the ability to manually change them in the scores measures table. Once all the desired scores have been changed, the user, by pressing the “2. Update charts” button, will trigger an update process which calculates the new value components chart. This is especially useful when we have a lot of projects with default values. Figure 6.9 shows the total value of each one of the alternatives broken down by the five defined objectives. In addition, it shows the alternative's cost based on the project definition done previously. The way the tool allocates budget to the best alternatives is discussed in the next section.

## 6.7 Portfolio Assessment

The portfolio allocation uses the Solver optimization algorithm. In addition to the alternatives' value, cost had also to be considered in order to create that would provide the best project not only by value, but also by cost.

Now that the values for each one of the alternatives are defined, the alternative's cost should also be considered in the analysis.

The following figure illustrates the value vs. cost relationship for all of the 16 projects defined in the stewardship plan:

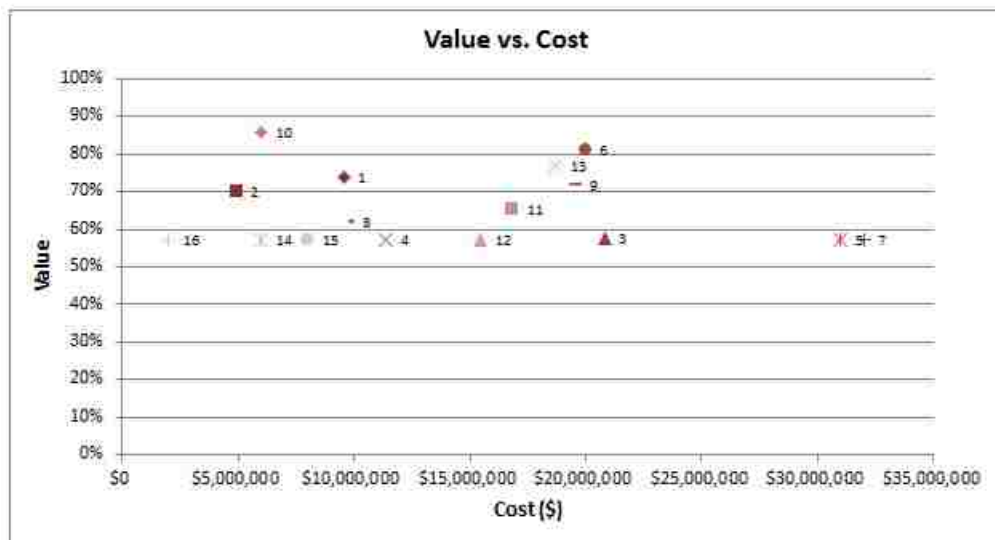


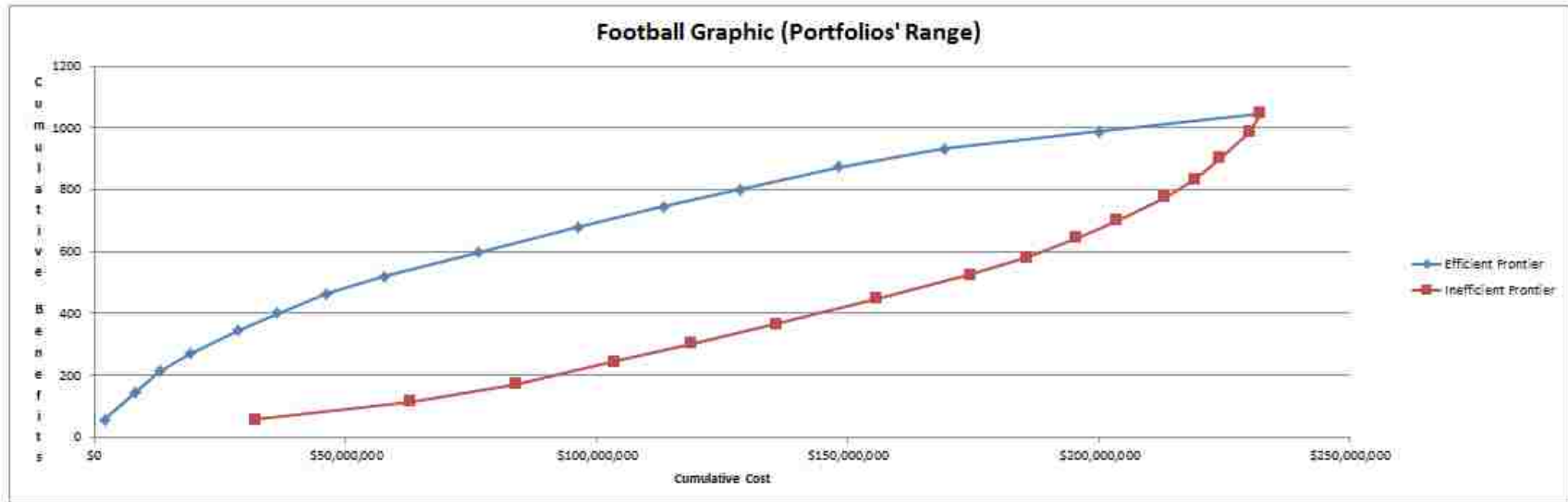
Figure 6.10 Value vs. Cost Plot

The idea here is to pick alternatives that provide the greatest value at a lowest cost, or in other words, the biggest bang for the buck. It is necessary to understand a prioritization method that allows measuring this relationship, and start allocating the budget towards the defined prioritization.

The Prioritization Index is a common prioritization technique that is used in portfolio allocation, which is defined by the ratio between the value and the cost of the alternative as shown below:

$$\text{Priority Index} = \frac{\text{Value of alternative}}{\text{Cost of the alternative}}$$

The Priority Index is calculated for each one of the projects, and then sort them by greatest priority index. We want to have an understanding of what the best vs. worst portfolios looks like, which is illustrated in what the decision analysis community refers to as the football graph, which is illustrated in the following figure:



Project	COST	VALU	ValueCo	Cum. Benefit (Inc)	Cum. Cost (Inc)	Value (Dec)	Cost (Dec)	Cum. Value (Dec)	Cum. Cost (Dec)
16	\$2,000,000	57	2868	57	\$2,000,000	57.36	\$32,000,000	57	\$32,000,000
10	\$6,000,000	86	1429	143	\$8,000,000	57.36	\$31,000,000	115	\$63,000,000
2	\$4,950,000	70	1411	213	\$12,950,000	57.69	\$20,820,000	172	\$83,820,000
14	\$5,990,000	57	958	270	\$18,940,000	71.77	\$19,580,000	244	\$103,400,000
1	\$9,560,000	74	774	344	\$28,500,000	57.36	\$15,440,000	302	\$118,840,000
15	\$8,000,000	57	717	402	\$36,500,000	65.32	\$16,850,000	367	\$135,690,000
8	\$9,800,000	62	633	464	\$46,300,000	81.25	\$20,000,000	448	\$155,690,000
4	\$11,410,000	57	503	521	\$57,710,000	76.82	\$18,720,000	525	\$174,410,000
13	\$18,720,000	77	410	598	\$76,430,000	57.36	\$11,410,000	582	\$185,820,000
6	\$20,000,000	81	406	679	\$96,430,000	62.07	\$9,800,000	644	\$195,620,000
11	\$16,850,000	65	388	745	\$113,280,000	57.36	\$8,000,000	702	\$203,620,000
12	\$15,440,000	57	371	802	\$128,720,000	74.04	\$9,560,000	776	\$213,180,000
9	\$19,580,000	72	367	874	\$148,300,000	57.36	\$5,990,000	833	\$219,170,000
3	\$20,820,000	58	277	931	\$169,120,000	69.86	\$4,950,000	903	\$224,120,000
5	\$31,000,000	57	185	989	\$200,120,000	85.74	\$6,000,000	989	\$230,120,000
7	\$32,000,000	57	179	1046	\$232,120,000	57.36	\$2,000,000	1046	\$232,120,000

Figure 6.11 Football Graphic (Range of possible portfolios)



As shown in the figure above, the alternatives are sorted by priority index. The Efficient frontier, or blue line in the figure, represents the best possible value that can be achieved for the least possible amount of money. The inefficient frontier represents the lowest possible value for the maximum amount of money. The figure gives us visibility in order to understand how much value my total portfolio could achieve, assuming that there is no budget constraint. The budget constraint is represented by a line in the y-axis, which limits the number of alternatives the optimization algorithm can choose from. We want to construct an algorithm that is as close as the efficient frontier as possible, so we can get the highest value of a portfolio, by the lowest cost.

In reality, stakeholders will not have the same preference for the alternatives. There might be some projects that are considered as a requirement and should be executed, or there might be some restrictions about the number of projects that can be executed for a specific type of project (Ex. Research Buildings). These and other realities create the necessity to introduce the concept of constraints.

Constraints are basically restrictions that limit the optimization model variables according to the stakeholder needs. As the constraints in the model increase, the overall value of the portfolio will stay the same or decrease. There might be a point where adding constraints will make the result of the optimization model infeasible. For example, let's assume that we have 4 projects with a cost of 10,000 each, and a budget of 30,000. Assuming as well that there is a constraint that specifies that all projects should be funded for the given budget, the solution to this optimization problem would be infeasible,.

Having a set of alternatives  $I$ , where each alternative  $i$  has a value of  $v_i$ , and  $y_i$  is a binary variable that defines whether the project is funded or not, the objective function will be to maximize the value of the portfolio by adding the value of each funded project. The objective function is expressed below: As described earlier, constraints should also be defined in order to consider the stakeholder's requirements. The first constraint that should be considered is the budget for the portfolio. Our final model for optimization, considering the budget as the only constraints would be:

Sets:

$I$  = set of alternatives  $i$

Indices:

$i$  = alternatives

Parameters:

$v_i$  = value for alternative  $i$

$k$  = budget available in the planning horizon

$c_i$  = cost for alternative  $i$

Decision Variables:

$$y_i \begin{cases} 1, & \text{if alternative } i \text{ is funded} \\ 0, & \text{otherwise} \end{cases}$$

Objective Function:

$$\max \sum_{i \in I} v_i y_i$$

Constraints:

st.

$$\sum_{i \in I} c_i y_i \leq k \quad (1)$$

$$y \in \{0,1\} \quad (2)$$

The previous optimization problem maximizes the alternatives' value with budget being the only constraint. The optimization results are discussed in the *Results* chapter. In reality, there were some additional constraints that the FAMA stakeholders wanted to include. Excluding specific projects, allowing partial funding, or minimum and maximum percentages where among the constraints defined in the model, which are discussed in the next section.

The stakeholders have the ability to run the model with the optimization problem defined in the next section, as well as adding some constraints that might give them additional visibility in case they want to analyze some set of alternatives as opposed to all of them. The optimization problem defined earlier changes depending on the constraints the user defines. The following figure shows the Portfolio Assessment Options Menu where the user has the ability to add some additional constraints if needed:

## PORTFOLIO ASSESMENT OPTIONS

Calculate Portfolio

1.- Partial Budgeting

Go Back to Main Menu

2. Specific Projects Constraints

Refresh

PROJECT_NBR	PROJECT_DESCRIPTION	Min	Max
<input checked="" type="checkbox"/> 1	KIMPEL HALL / CLASSROOM BLOCK (COMPLETION)		
<input checked="" type="checkbox"/> 2	SCIENCE BUILDING (COMPLETION)		
<input checked="" type="checkbox"/> 3	FINE ARTS CENTER (WHOLE BUILDING)		
<input checked="" type="checkbox"/> 4	LIBRARY OFFSITE STORAGE BUILDING (STACKS REMOVED)		
<input checked="" type="checkbox"/> 5	PLAYING FIELDS FOR UNIVERSITY RECREATION (THREE SITES)		
<input checked="" type="checkbox"/> 6	BUSINESS BUILDING / SYSTEMS RENEWAL (PARTIAL)		
<input checked="" type="checkbox"/> 7	RESEARCH CENTER AT ARKANSAS RESEARCH & TECHNOLOGY PARK		
<input checked="" type="checkbox"/> 8	HUMAN ENVIRONMENTAL SCIENCES BUILDING (COMPLETION)		
<input checked="" type="checkbox"/> 9	JOHN A WHITE JR ENGINEERING HALL (COMPLETION)		
<input checked="" type="checkbox"/> 10	ARKANSAS UNION / CONNECTIONS & NORTH TERRACE PAVILION		
<input checked="" type="checkbox"/> 11	MEMORIAL HALL (COMPLETION-INTERIOR)		
<input checked="" type="checkbox"/> 12	MULLINS LIBRARY (REPURPOSE STACK AREA)		
<input checked="" type="checkbox"/> 13	AGRICULTURE BUILDING (WHOLE BUILDING)		
<input checked="" type="checkbox"/> 14	NANOSCALE MATERIAL SCIENCE & ENG / THIRD FLOOR LAB BUILD OUT		
<input checked="" type="checkbox"/> 15	CENTRAL QUAD RENOVATION & EXPANSION / WEST TERRACE MULLINS MODIFICATIONS		
<input checked="" type="checkbox"/> 16	CAMPUS NORTH/SOUTH ENTRANCES RENEWAL & UPGRADE		

Figure 6.12 Portfolio Assessment Options

Partial budgeting is the first constraint the user is able to select. If partial budgeting is selected, then the decision variable, as well as the second constraint in the initial model changes. The decision variables changes from being a binary variable to a float variable.

$$y \in \{0,1\} \rightarrow y \in [0,1]$$

The decision variable definition changes from being a discrete variable, to a continuous one defined from the 0 to 1 range.

Assuming that the stakeholders want to exclude a specific project out of the optimization algorithm, the respective check box has to be updated in the second constraint menu. If unchecked, the optimization model excludes that particular alternative from by adding a constraint to the model:

$$y_i \leq 0$$

Where  $i$  is the alternative that is excluded from the optimization problem.

Finally, if both constraints are selected, the user has the ability to define minimum and maximum percentages for a specific alternative. As an example, if the user wants to force the optimization algorithm to allocate at least 30% of the total project total cost to John A. White Engineering Hall, and have a maximum allocated budget to Kimpel Hall of 70%, the user by defining this percentages in the maximum and minimum values, will be forcing the optimization problem to allocate budget with these additional constraints:

$$\text{Max: } y_i \leq UB\%_i$$

$$\text{Min: } y_i \geq LB\%_i$$

## **Chapter 7: Results**

Based on the decision hierarchy developed by the FAMA stakeholders, one of the framing procedures that was established excluded projects that are not E&G. Out of the total 16 projects in the Stewardship Plan, Projects 4,5,15 and 16 were excluded from the analysis. These projects did not have any historical utilization rates because of their project type, in addition, classes are not scheduled in any of these projects, so it would not provide any value to the students, faculty or any education stakeholders. Two different scenarios were considered, one being the optimization problem with binary variables (yes/no decisions), and the other one allowing partial funding to the mix. The figures in the following pages illustrate the tool's output for both scenarios:



Figure 7.1 Portfolio Allocation result based on (yes/no) decisions

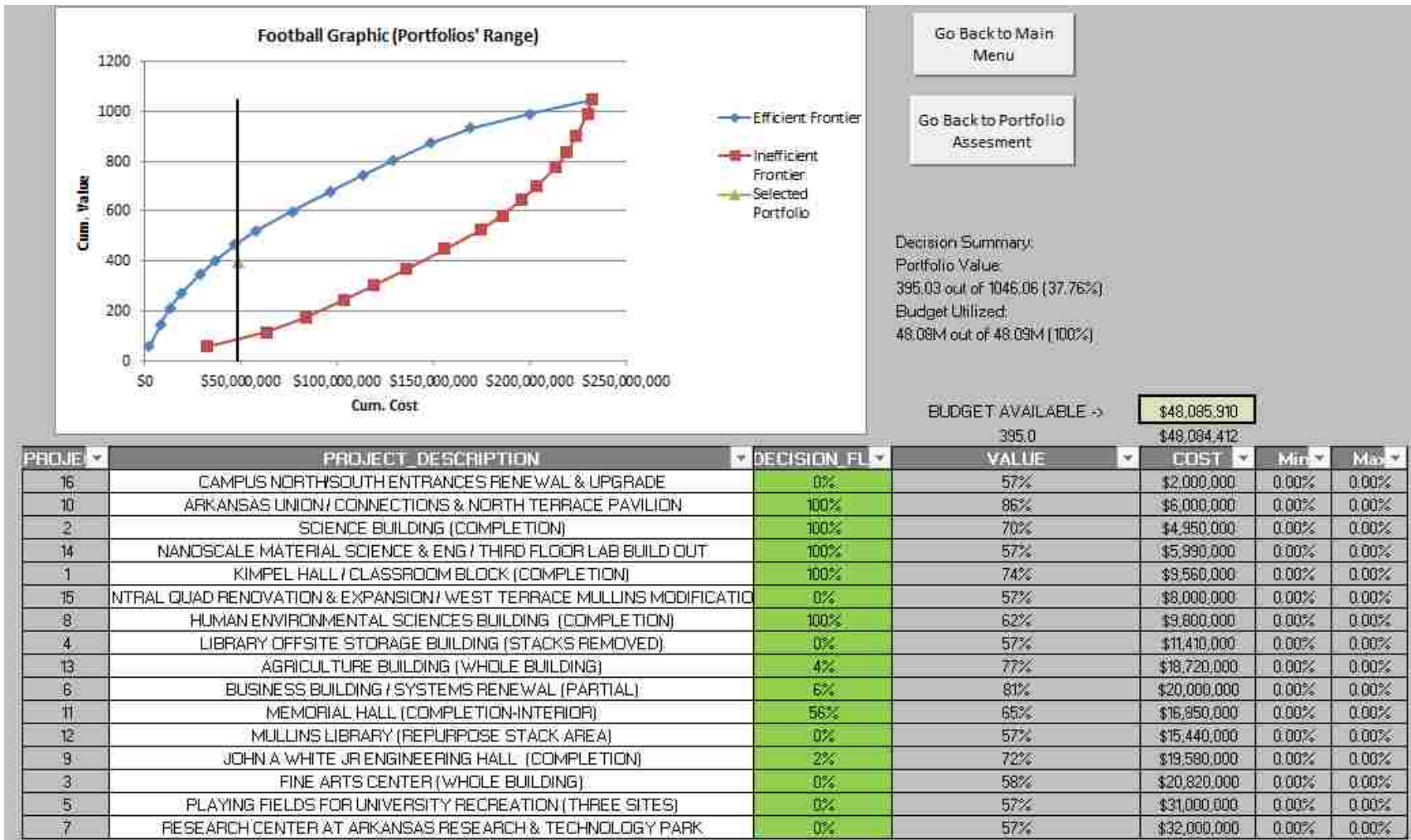


Figure 7.2 Portfolio allocation result allowing partial funding



As we can see from figure 7.1, based on the optimization result, there are 5 projects that we should fund. The projects are sorted by priority index, so the Arkansas Union is the project with highest bang for the buck. Based on the football graph, we can see that the budget available is really low compared to what the cost of all the alternatives is (just 20.71%). Therefore, it is really important allocated the budget available we have as efficiently as possible. The green point in figure 6.1 illustrates the value of the portfolio that was achieved, as well as the budget used. The decision summary provides useful information that allow the stakeholders to understand the value achieved, as well as the budget utilized. A 35.2% of the total value of the portfolio is achieved based on this decision, being the budget the only constraint run in the model.

In the second scenario illustrated in figure 7.2, we can see that in addition to the original 5 projects that were allocated with the previous model, there are 4 projects that have the opportunity of being partially funded. One important note is that if the minimum ranges are not defined in the portfolio assessment options menu, the percentage allocated to a specific project can be as low as 1%, in reality, we are certain that this is not going to happen. The user can run additional scenarios exclude the project that have really low allocation percentages based on these results, to then have a realistic visibility of the total value of the portfolio achieved. The portfolio value achieved is higher than yes/no decisions (37.76%), and the budget utilized is close to a 100%. This infers that having partial funding is beneficial as we are utilizing our resources the best way possible. Memorial Hall is the only project that is a candidate for partial funding in reality, having a funding opportunity of more than half of its project cost. The dynamic way the tool is built allows the FAMA stakeholders to draw different scenarios that will support their planning and implementation decisions.

## Chapter 8: Conclusions

Below are some important conclusions the stakeholders should be aware of when using the developed Integrated Strategic Planning Tool.

The strategic tool is an integrated model that assesses the best portfolio decision based on quantitative values only. It does not assess some qualitative values that might influence in the decision. FAMA stakeholders might have a different way of accessing qualitative factor that should be taken into consideration for the decision as opposed to the Board of Trustees, so discussions to level the playing field have to take place before reaching to a final decision.

The Strategic Tool provides guidance rather than making decisions. It is a quantitative value added way of allocating budget. In the end, decision makers will always make the best judgment.

The tool is a guidance source that can help with such decision.

- Additional constraints or objectives could be considered, so the model developed provides a baseline that can be modified and enhanced according to the stakeholders preferences and needs in the future.
- The utilization rates and scheduling preferences might become outdated in the long run, so the FAMA stakeholders will need to make sure that the utilization rates built in the tool are the most update ones based on conversations with central scheduling.
- No model is ever perfect, the project allocation was built in the best way possible with assumptions that are discussed in this work, however, it gives the FAMA stakeholders a new way of evaluating their priorities for construction alternatives, to ensure that the ultimate University's goal is met, providing the best facilities for academic excellence.

## 8.1 Future Research

The following are ideas for future research:

- The value hierarchy does not have a function for research capability. Since becoming one of the top 50 research schools is one of the goals mentioned in the “Transforming the Flagship” document, an additional function could be added in the functional value hierarchy to capture research space in the construction alternatives’ value.
- Constraints in the optimization model can be added to allow the FAMA stakeholders to construct additional scenarios. Limiting the alternatives funding by construction space could be one of them. The gross square feet (GSF) is a parameter that is already included in each alternative’s definition, which can be used to add a new constraint in the portfolio analysis, in a similar way the budget allocation percentage was considered.
- The construction time for each one of the alternatives was not considered in the optimization problem. As an example, 3 month projects might be preferred to 3 years projects based on the urgency the University has to fill unprecedented increasing scheduling demand. Adding construction time to the value hierarchy could also be another way of considering assessing this factor.
- The functional value hierarchy represents the interests of FAMA stakeholders. Scheduling preferences is the only objective in the value hierarchy that considers stakeholders preferences outside of FAMA. Having additional meetings with student representatives, state regulators, and other stakeholders that might be affected by constructions could be a good start to add some additional functions in the defined value hierarchy that assesses everyone’s preferences.

- Cost and schedule uncertainty could be accessed as a factor in the model. For projects of the same cost and time, FAMA would prefer a project that had less potential to exceed cost goal or schedule goal.

## **Bibliography**

Fasolo, Barbara, Alec Morton and Winterfeldt Detlof von. "Behavioral Issues in Portfolio Decision Analysis." Salo, Ahti, Jeffrey Keisler and Alec Morton. *Portfolio Decision Analysis: Improved Methods for Resource Allocation*. Springer, 2011. Print.

Gearhart, G. David. "Transforming the Flagship." (2014): 1-20. Print.

Keeney, Ralph L. "Making Better Decision Makers." *INFORMS*. 2004. 193-204. Print.

Keisler, Jeffrey. "Portfolio Decision Quality." Salo, Ahti, Jeffrey Kesiler and Alec Morton. *Portfolio Decision Analysis*. Springer, 2011. Print.

Kirkwood, Craig W. *Strategic Decision Making*. 1996. Print.

Matheson, D. and J. Matheson. "The Smart Organization." *Boston: Harvard Business School Press*. (1998). Print.

Parnell, Gregory S., et al. *Handbook of Decision Analysis*. Wiley & Sons, 2013. Print.

Parnell, Gregory S., Patrick J. Driscoll and Dale L. Henderson. *Decision Making in Systems Engineering and Management*. Wiley and Sons, 2010. Print.

Phillips, Lawrence D. "The Royal Navy's Type 45 Story: A Case Study." Salo, Ahti, Jeffrey Keisler and Alec Morton. *Portfolio Decision Analysis*. Springer, 2011. Print.

*The Office of Institutional Research: University of Arkansas*. 2014. Web. 15 09 2014.

## Appendix A



UNIVERSITY OF  
ARKANSAS

Facilities Management  
Campus Planning and Capital Programming

January 18, 2013

**MEMO**

To: Scott Varady, General Counsel

Re: University of Arkansas landholdings in Washington County, Arkansas

In response to your request, we have developed the following table of university landholdings within the county. Acreages were calculated from a geographic information system using the parcel outlines provided by Washington County as of mid-December 2012. These figures do not include vacated alleys, easements, streets, or other geometries outside the parcels themselves. Therefore, while we feel confident in the relative accuracy of these numbers, they do not take the place of a professional survey.

<b>University of Arkansas</b>	
Main Campus (includes athletics south and ARTP west campus)	509.69
Uptown Campus	9.34
Natural and wooded sites (includes ARTP east, Garland hillside, Markham Hill)	121.67
<i>subtotal</i>	<b>640.7</b>
<b>Division of Agriculture</b>	
Arkansas Agricultural Research and Extension Center	705.37
Savoy Research & Extension Complex*	2886.93
Physiology Farm, Walker Tract, Baldwin Tract, and one small parcel by Goshen	381.78
<i>subtotal</i>	<b>3974.08</b>
<b>Other</b>	
Former SEFOR site	618.41
Land leased to the City of Fayetteville (Asbell Soccer Fields)**	25.11
Nadine Baum Studios	1.44
<i>subtotal</i>	<b>644.96</b>
<b>Total university-owned parcels in Washington County</b>	<b>5259.74</b>

\*There are three "holes" in the landholdings, which appear to be Federally owned. This acreage is not included.

\*\*The university uses 9.04 acres of city property along Indian Trail in exchange for city use of these fields.

Sincerely,

Jill Anthes, Campus Planner

cc: Mike Johnson  
James Ezell

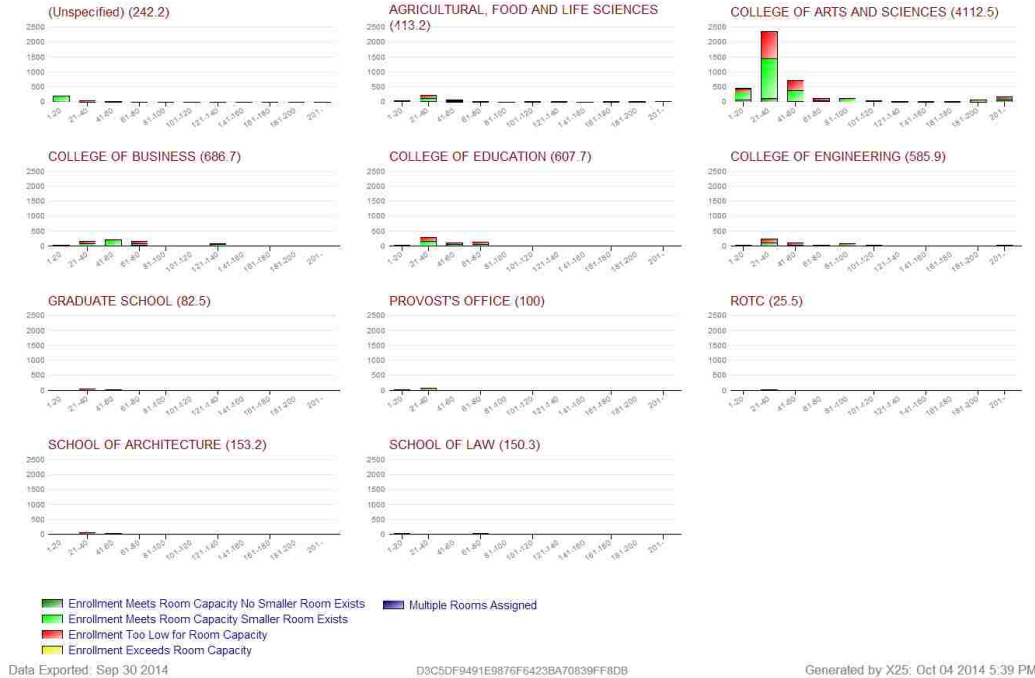
C100 Facilities Management • Fayetteville, AR 72701 • 479-575-6983 • [planning.uark.edu](mailto:planning.uark.edu)  
The University of Arkansas is an equal opportunity/affirmative action institution.

### A.1 University of Arkansas landholdings memo

The memo shows The University of Arkansas landholdings within the county in the beginning of 2013. The document helped understand the current extension of the constructions the University holds, as well as evaluating how the new prospective construction alternatives will add to the different Divisions of the University.



**Class/Event Placement by Room Capacity**  
 Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
 From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014  
 Meeting Hours Plotted for Each College Group (Total Meeting Hours)



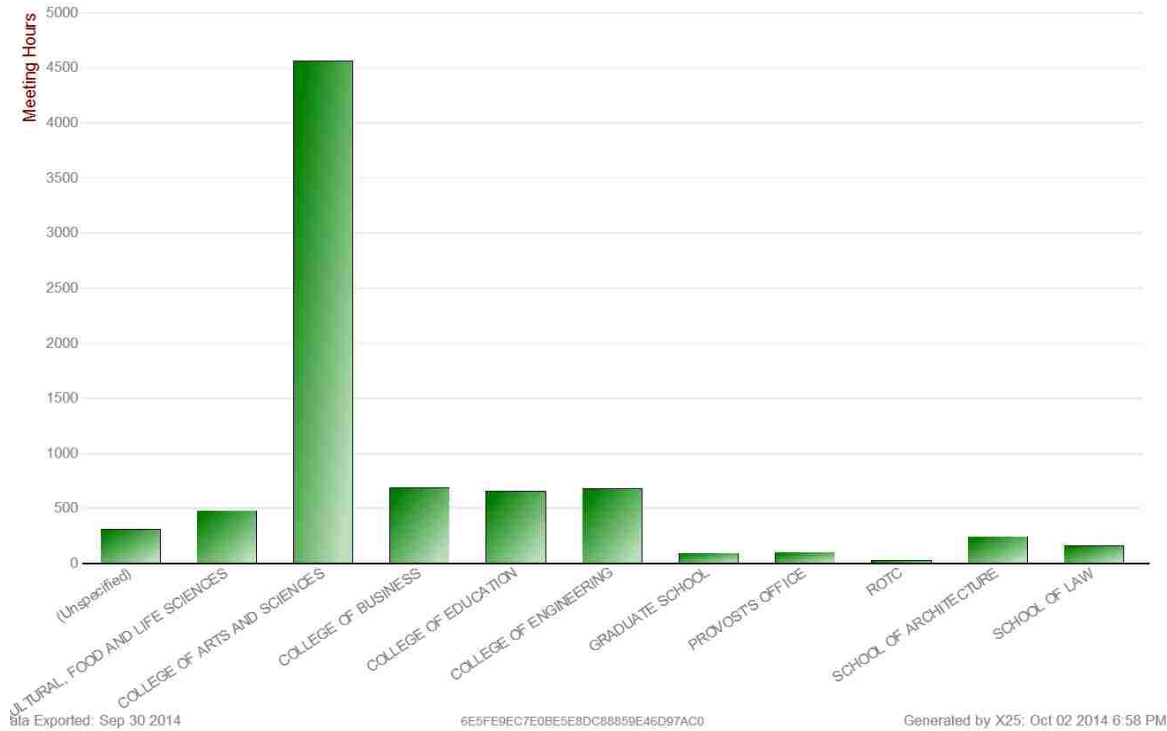
### A.3 Room capacity placement by College

The figure shows the actual student enrollment per room capacity (in ranges of 20) for each building. As we can see, the College of Arts and Sciences is the one having the most meeting hours in the analyzed week. Classes ranging in a capacity between 21 and 40 are the most used on campus. In addition, we can see how around 40% of that total scheduling for the 21-40 example in the College of Arts falls below the room capacity, which implies that the average class size falls in the mid to low 20s.



### Class/Event Distribution

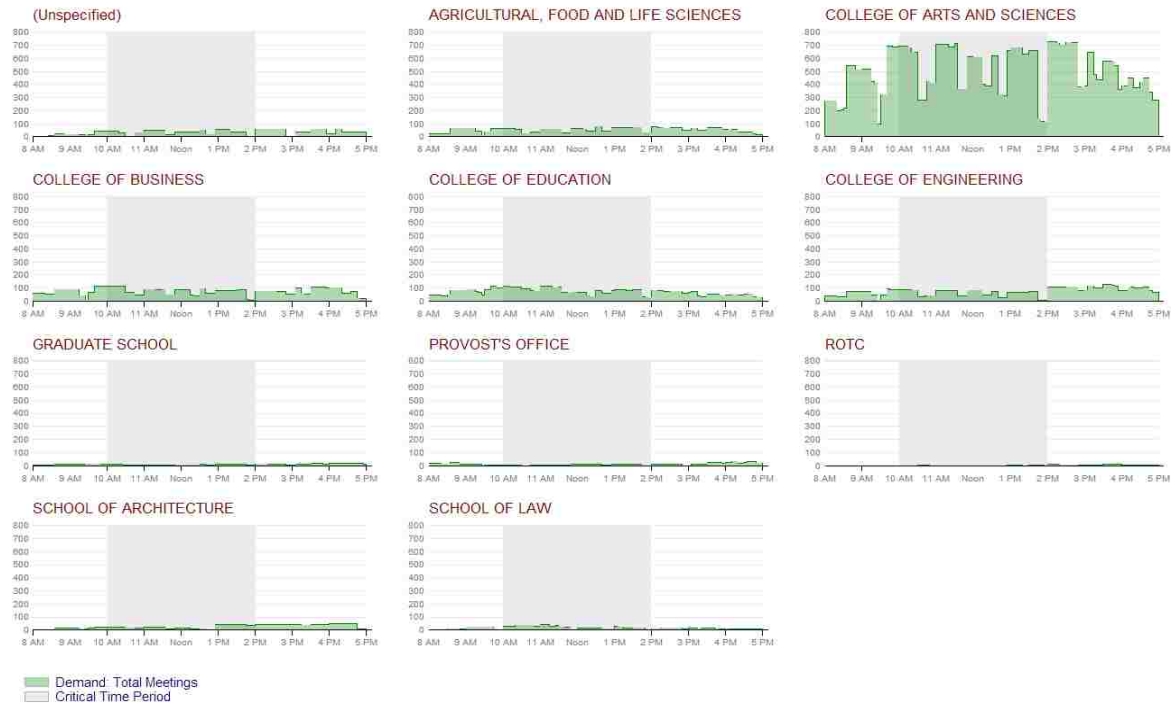
Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014  
Total Meeting Hours: 7991.8



#### A.4 Meeting Hours per College

This figure is another way of representing the meeting hours per college. The College of Arts and Sciences is the one having the most meeting hours. This shows a strong relationship between the building that is used the most (Kimpel Hall) and this college. A lot of the college's classes are scheduled there. The second position falls into three different colleges, all of them having similar demands. Bell Engineering and the Walton College of Business are some building examples which meetings hours are driven by these Colleges.

**Demand by Time**  
 Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
 From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014  
 Total Meetings Plotted for Each College Group

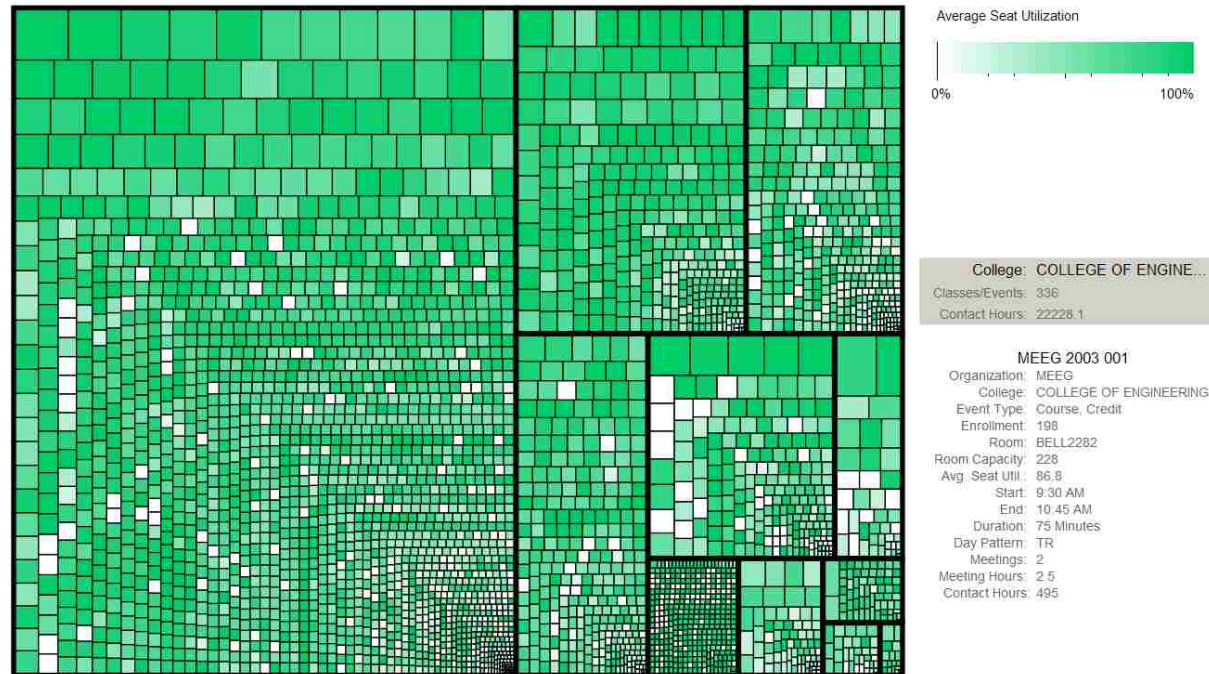


**A.5 Meetings planned per college throughout the day**

The figure represents the number of meetings per building in a University's business day. The gray range (10 AM to 2 PM) represents the business peak hours for scheduling. Each college has a limit in the number of classes that can be schedule in peak time. Each department in each college should plan accordingly to provide some time alternatives for their classes. If the peak's capacity is reached, Scheduler will automatically look and allocate for a substitute room that matches the criteria defined by the department.

## Class/Event Mapping

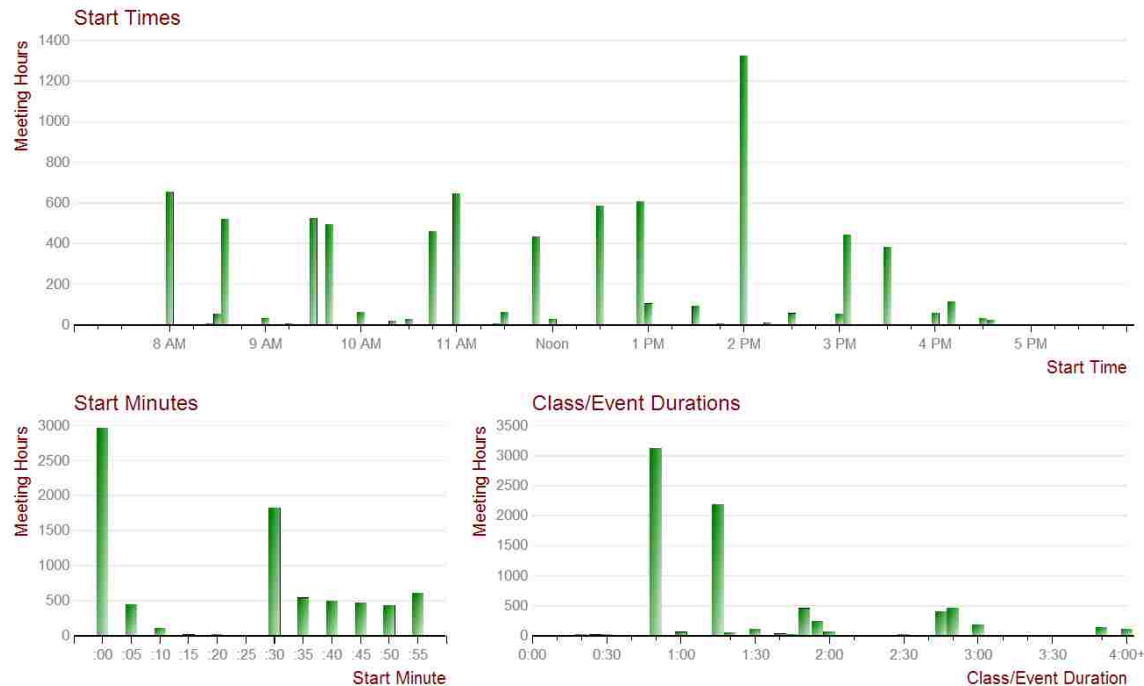
Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014  
3661 Classes/Events, Grouped by College/Division (11), Sized by Contact Hours (258469.4)



### A.6 Class Mapping per Room/College

The figure shows how X25 allows visualizing the average seat utilization across all rooms per building. This is really useful when trying to understand which class about of each college is the one that is used the most, as well as in which building it is scheduled. The bigger the square representing a room, the bigger the capacity. The greener the square, the better the average seat utilization in that room. Some squares are white, which allows to identify rooms that are not being used at all. Some might be special rooms that are not available for education purposes, but some of them will highlight scheduling inefficiencies that can be improved.

**Class/Event Time Distribution**  
 Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
 From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014  
 Total Meeting Hours Reported on: 7991.78



Data Exported: Sep 30 2014

80491DCABE1CED8D9C8800015E630205

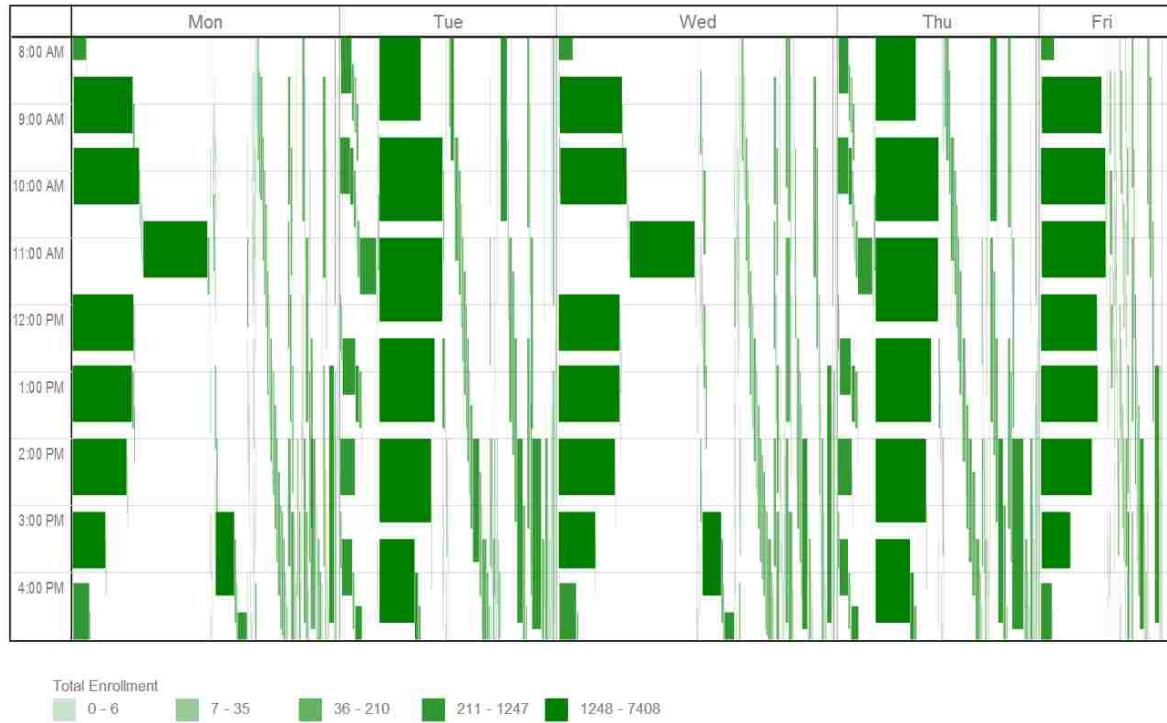
Generated by X25: Oct 01 2014 1:46 PM

**A.7 Class/Event Time distribution throughout the day**

The figure represents the start time frequencies for a business day across all buildings. The scheduling peak (10 AM to 2 PM) is what limit classes starting from this time range to be overscheduled. As soon as the scheduling peak finishes, we can see a big bump in scheduling at 2 PM (over 1200 meeting hours). Starting at the hour sharp is the biggest trend in starting minutes (2900 hours), in addition, the two most frequent duration for a class are 50 minutes (3200 hours), and 80 minutes (2100 hours).

### Schedule Distribution

Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
 From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014



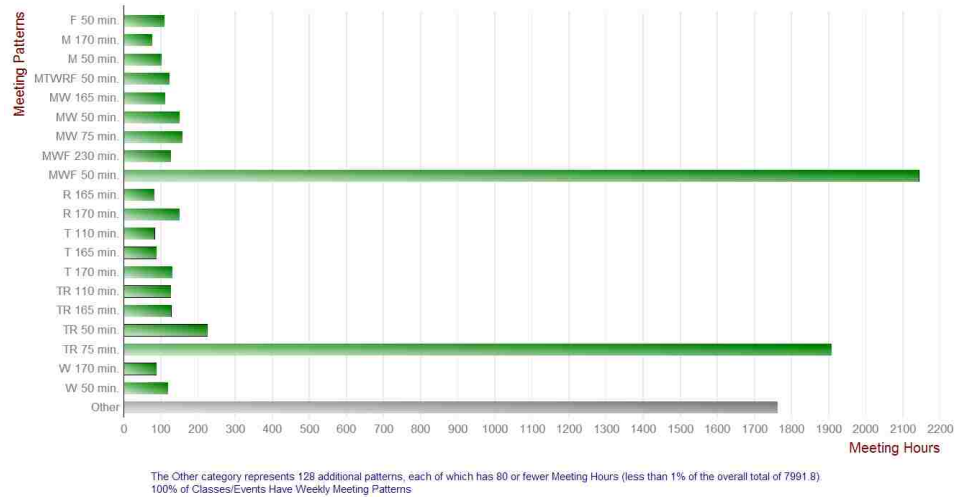
Data Exported: Sep 30 2014

4727556CA213FAAA3EDEEEAAA6728AD6

Generated by X25: Oct 04 2014 5:35 PM

A.8 Schedule distribution in a business week

Weekly Meeting Pattern Analysis  
 Fall 2014/Fall 2014 Census with ELC (2nd snapshot)  
 From 8:00 AM to 5:00 PM on Mon Tue Wed Thu Fri Week of Sep 08 2014  
 Total Meeting Hours Reported On: 7991.8



Data Exported: Sep 30 2014

80491DCABE1CED8D9C8800015E630205

Generated by X25: Oct 01 2014 1:46 PM

### A.9 Weekly Meeting Pattern

The figure represents the most frequent class patterns throughout a business week in the University. Based on the illustration, we can see that a 50 minute class, 3 times a week, is the pattern that is used most frequently (with around 2150 meeting hours). 75 minute classes, two times a week, is a pattern used commonly as well. The “other” bar represents classes which do not have a fixed scheduling meeting time. Example include: Drills, Senior Design Meetings, Labs, between others. Because they englobe different variable patterns that are group together, they provide some significant meeting hours in the figure.

	Fall 2013	Fall 2014	% of Total	% of Change
<b>STUDENT CAREER</b>				
<b>Undergraduate</b>	<b>21,009</b>	<b>21,836</b>	<b>83.2%</b>	<b>3.0%</b>
First-time Entering Freshmen - Degree Seeking	4,339	4,571	17.4%	5.3%
First-time Entering Freshmen - Non Degree Seeking	18	19	0.1%	5.6%
Transfer Freshmen	50	68	0.3%	36.0%
New Transfer	1,354	1,462	5.6%	8.0%
Readmit	580	667	2.5%	15.0%
Continuing	14,668	14,969	57.1%	2.1%
Correspondence Only	0	80	0.3%	N/A
<b>Graduate</b>	<b>3,942</b>	<b>4,022</b>	<b>15.3%</b>	<b>2.0%</b>
First-time Entering - Degree Seeking	1,172	1,178	4.5%	0.5%
First-time Entering - Non Degree Seeking	62	116	0.4%	87.1%
Continuing	2,567	2,578	9.8%	0.4%
Readmit	141	150	0.6%	6.4%
<b>Law</b>	<b>390</b>	<b>379</b>	<b>1.4%</b>	<b>-2.8%</b>
First-time Entering - Degree Seeking	134	146	0.6%	9.0%
First-time Entering - Non Degree Seeking	3	1	0.0%	-66.7%
Continuing	251	232	0.9%	-7.6%
Readmit	2	0	0.0%	-100.0%
<b>Total</b>	<b>25,341</b>	<b>26,217</b>	<b>100.0%</b>	<b>3.5%</b>
<b>CURRENT LEGAL RESIDENCE</b>				
Resident	15,307	15,329	58.4%	0.1%
Non-Resident	8,647	9,383	35.8%	8.5%
Foreign (International)	1,387	1,525	5.8%	9.9%
<b>Total</b>	<b>25,341</b>	<b>26,217</b>	<b>100.0%</b>	<b>3.5%</b>
<b>GENDER</b>				
Female	12,740	13,395	51.1%	5.1%
Male	12,601	12,842	48.9%	1.9%
<b>Total</b>	<b>25,341</b>	<b>26,217</b>	<b>100.0%</b>	<b>3.5%</b>
<b>ETHNICITY/RACE</b>				
Hispanic and any race	1,507	1,666	6.3%	10.6%
American Indian Only	327	323	1.3%	-1.2%
Asian Only	592	649	2.5%	9.6%
African American Only	1,284	1,330	5.1%	3.6%
Foreign (International)	1,387	1,525	5.8%	9.9%
Hawaiian Only	18	22	0.1%	22.2%
Caucasian Only	19,375	19,813	75.5%	2.3%
Two or More Races	751	778	3.0%	3.6%
Not Available	100	131	0.5%	31.0%
<b>Total</b>	<b>25,341</b>	<b>26,217</b>	<b>100.0%</b>	<b>3.5%</b>
<b>Total Minority<sup>1</sup></b>	<b>4,479</b>	<b>4,768</b>	<b>18.2%</b>	<b>6.5%</b>
<b>ARKANSAS ACADEMIC CHALLENGE SCHOLARSHIP<sup>2</sup></b>				
Traditional Students	5,341	5,528	91.9%	3.5%
Continuing Recipients (Part I)	13	0	0.0%	-100.0%
Non-Traditional Students	367	474	7.9%	29.2%
Current Achievers	135	10	0.2%	-92.6%
<b>Total</b>	<b>5,856</b>	<b>6,012</b>	<b>100.0%</b>	<b>2.7%</b>

<sup>1</sup> Minority is defined by the following ethnicity/races: Hispanic, American Indian, African American, Asian, Hawaiian, and Two or More Race.

<sup>2</sup> Students who are eligible to receive funds; does not include students who are not enrolled in enough hours or who are not enrolled in an eligible program.

**NOTE:**

\* Data for this report includes on-schedule, on and off-campus enrollment.

\* Effective Summer 1 2013, total enrollment includes intersession term enrollment.

## A.10 Enrollment Report Fall 2014

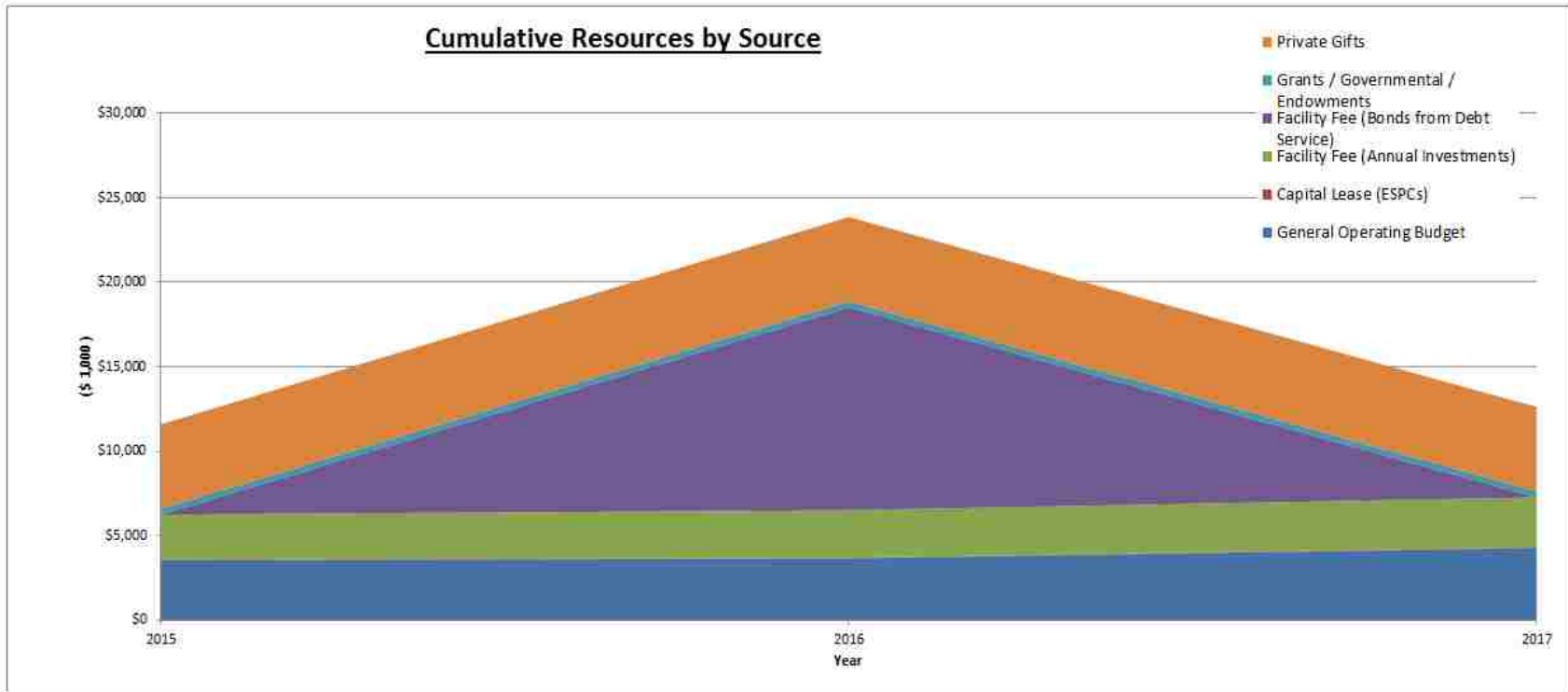
This report shows the enrollment numbers for Fall 2014 at the University of Arkansas. The report is broken down into different sections that allow understanding the different type of students enrolled in the University. Gender, immigration status or ethnicity is among some of the categories that are present in this report.

FUNDING RESOURCES (in thousands)		Required Resources	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
<b>OPERATING BUDGET</b>			\$ 1,000	\$ 723	\$ 552			Add'l Budget Requirement										
LVL 3 Planned Renewal (non-HVAC)	\$ 4,370	\$ 176	\$ 175	\$ -	\$ 376	\$ 227	\$ 250	\$ 300	\$ 325	\$ 325	\$ 325	\$ 325	\$ 325	\$ 325	\$ 325	\$ 325	\$ 325	\$ 325
Handscape	\$ 6,237	\$ 232	\$ 35	\$ 105	\$ 436	\$ 274	\$ 325	\$ 425	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500
ADA / ILS / Building Envelope	\$ 12,071	\$ 482	\$ 210	\$ 423	\$ 711	\$ 645	\$ 700	\$ 800	\$ 900	\$ 900	\$ 900	\$ 900	\$ 900	\$ 900	\$ 900	\$ 900	\$ 900	\$ 900
LVL 3 Planned Renewal (HVAC)	\$ 7,553	\$ 200	\$ 364	\$ 24	\$ 634	\$ 345	\$ 425	\$ 500	\$ 569	\$ 569	\$ 569	\$ 569	\$ 569	\$ 569	\$ 569	\$ 569	\$ 569	\$ 569
Delta T Capital Renewal	\$ 18,572	\$ -	\$ -	\$ -	\$ 713	\$ 1,453	\$ 300	\$ 1,250	\$ 1,450	\$ 1,600	\$ 1,600	\$ 1,600	\$ 1,600	\$ 1,600	\$ 1,600	\$ 1,600	\$ 1,600	\$ 1,600
Mullins Creek Restoration - City of Fayetteville match	\$ 175				\$ 25		\$ 150											
Mullins Creek Restoration - Beaver WD	\$ 550				\$ 200		\$ 350											
Mullins Creek Restoration - UA Match	\$ 550				\$ 200		\$ 350											
ARRA Stimulus (one time funding)	\$ 4,000		\$ 4,000															
Signage & Way Finding (AUX funding)	\$ 25					\$ 25												
ADA Compliance Review / Mitigation Design (AUX)	\$ -																	
Capital Lease Remainder - Energy / CRDM	\$ 1,067		\$ 1,067															
<b>ENERGY SAVINGS PERFORMANCE CONTRACTS</b>																		
<b>Net Savings (Utility Savings less Lease Payment)</b>																		
Poultry Science - ESPCI	\$ 1,702	\$ 0	\$ 0	\$ 0	\$ 0	\$ 7	\$ 7	\$ 7	\$ 7	\$ 7	\$ 7	\$ 7	\$ 7	\$ 3	\$ 413	\$ 413	\$ 413	\$ 413
Campus Wide Improvements - ESPCI (a)	\$ 12,442	\$ 2	\$ 2	\$ 1	\$ 2	\$ 1	\$ 55	\$ 333	\$ 471	\$ 611	\$ 757	\$ 911	\$ 1,072	\$ 1,242	\$ 1,420	\$ 1,607	\$ 1,807	\$ 3,951
Campus Wide Improvements - ESPCI (b)	\$ 1,522	\$ 14	\$ 14	\$ 19	\$ 24	\$ 30	\$ 35	\$ 42	\$ 47	\$ 53	\$ 59	\$ 65	\$ 72	\$ 78	\$ 328	\$ 328	\$ 328	\$ 328
<b>Generated Available Capital from Energy Savings</b>																		
Poultry Science - ESPCI	\$ 3,800	\$ 3,800																
Campus Wide Improvements - ESPCI (a)	\$ 22,959	\$ 20,000	\$ 2,959															
Campus Wide Improvements - ESPCI (b)	\$ 2,237	\$ 1,500	\$ 737															
<b>SUB-TOTAL OPERATING FUND SOURCES</b>		<b>\$ 99,952</b>	<b>\$ 4,800</b>	<b>\$ 27,306</b>	<b>\$ 4,328</b>	<b>\$ 3,327</b>	<b>\$ 3,007</b>	<b>\$ 3,547</b>	<b>\$ 3,663</b>	<b>\$ 4,268</b>	<b>\$ 4,564</b>	<b>\$ 4,716</b>	<b>\$ 4,876</b>	<b>\$ 5,040</b>	<b>\$ 5,627</b>	<b>\$ 6,055</b>	<b>\$ 6,242</b>	<b>\$ 8,586</b>
<b>MAJOR CAPITAL PROJECTS</b>																		
<b>FACILITY FEE &amp; RELATED BONDS</b>					5 Year Facility Credit Hour Fee													
Annual Investment	\$ 88,064	\$ 860	\$ 1,820	\$ 3,001	\$ 4,426	\$ 5,832	\$ 6,060	\$ 6,298	\$ 6,535	\$ 6,654	\$ 6,654	\$ 6,654	\$ 6,654	\$ 6,654	\$ 6,654	\$ 6,654	\$ 6,654	\$ 6,654
(80,139)	\$ (325)	\$ (325)	\$ (873)	\$ (3,873)	\$ (5,288)	\$ (5,589)	\$ (6,030)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)	\$ (6,469)
FY 09/10/11/12/13/14/15 Bonded Debt	\$ 104,321	\$ 20,000	\$ 321	\$ 62,600	\$ 10,000		\$ 12,000											
<b>DIRECT CAPITAL FUNDING</b>																		
Dean's Capital Matching Fund	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
<b>GRANTS / ANCRC / MISC</b>																		
Grants / ANCRC	\$ 5,787			\$ 767	\$ 350	\$ 800	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350
Miscellaneous / Match Reqmt	\$ 250			\$ 200	\$ 50													
<b>PRIVATE GIFTS / DONORS</b>																		
University Development (general)	\$ 97,383																	\$ 97,383
University Development (ENGR Hall)	\$ 1,500					\$ 1,500												
University Development (Davis Hall)	\$ 4,000	\$ 4,000																
University Development (Nursing / CCD)	\$ 4,700			\$ 4,000	\$ 700													
University Development (Vol Walker Hall)	\$ 15,250			\$ 10,000	\$ 5,250													
University Development (Concert Hall)	\$ 12,000				\$ 12,000													
Fayetteville Campus Foundation	\$ 9,100				\$ 9,100													
<b>SUB-TOTAL CAPITAL FUNDING SOURCES</b>		<b>\$ 263,356</b>	<b>\$ 860</b>	<b>\$ 25,495</b>	<b>\$ 7,436</b>	<b>\$ 74,253</b>	<b>\$ 39,194</b>	<b>\$ 821</b>	<b>\$ 12,618</b>	<b>\$ 416</b>	<b>\$ 535</b>	<b>\$ 535</b>	<b>\$ 535</b>	<b>\$ 535</b>	<b>\$ 535</b>	<b>\$ 535</b>	<b>\$ 535</b>	<b>\$ 98,518</b>

### A.11 Budget Template Breakdown from FAMA

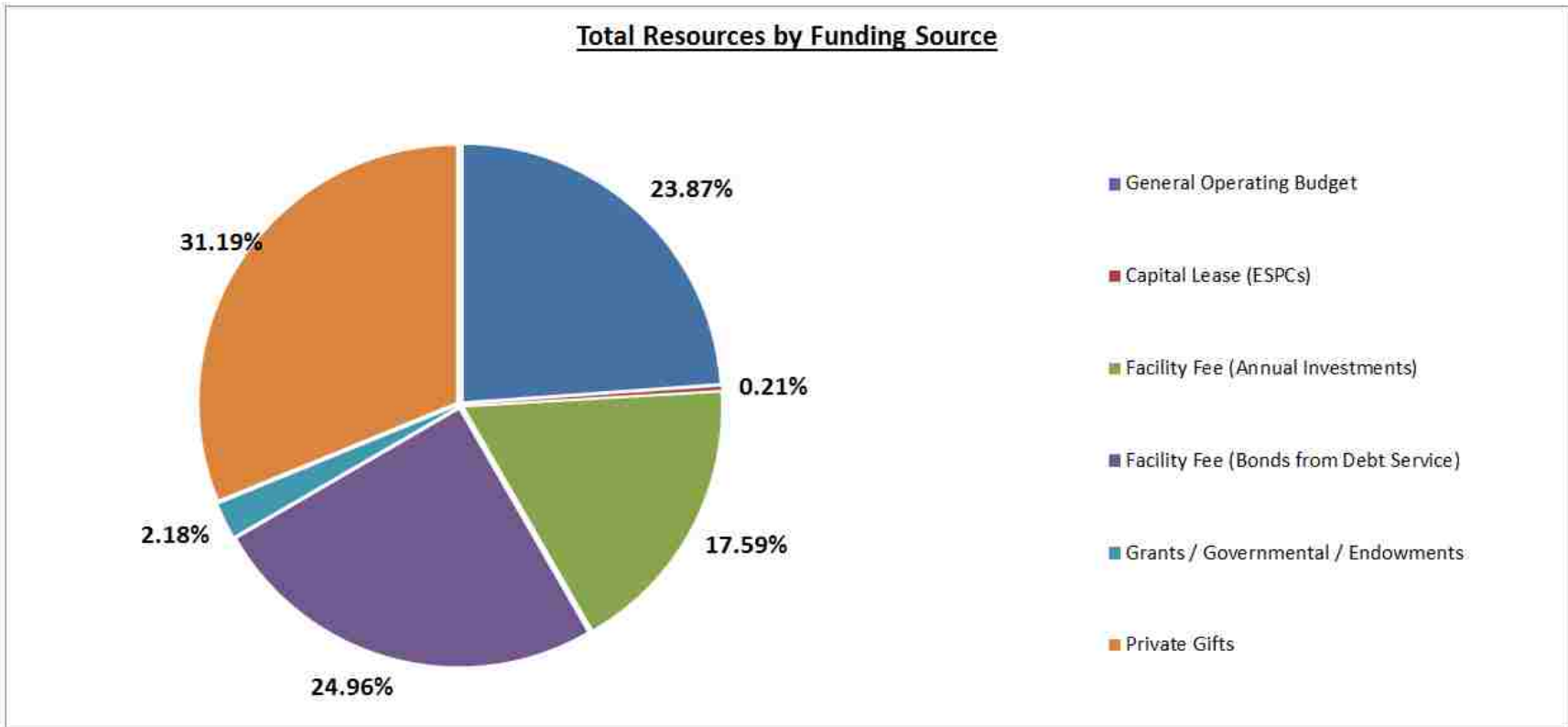
This figure shows the Excel spreadsheet the FAMA stakeholders use in order to document the different categories of budget they have available for construction projects. Each one of the six different categories defined in the budget modeled is included in this spreadsheet. The utility operations & maintenance director in FAMA is the one responsible for maintaining this document up to date. This is one of the key sources that allows to support the necessity of additional funding to the Board of Trustees. There are recurrent funding sources such as the facilities fee, as well as one time funding such as the ARRA stimulus. The recurrent funding sources will also change based on student enrollment and the facilities fee, so it is important to keep the document up to date.





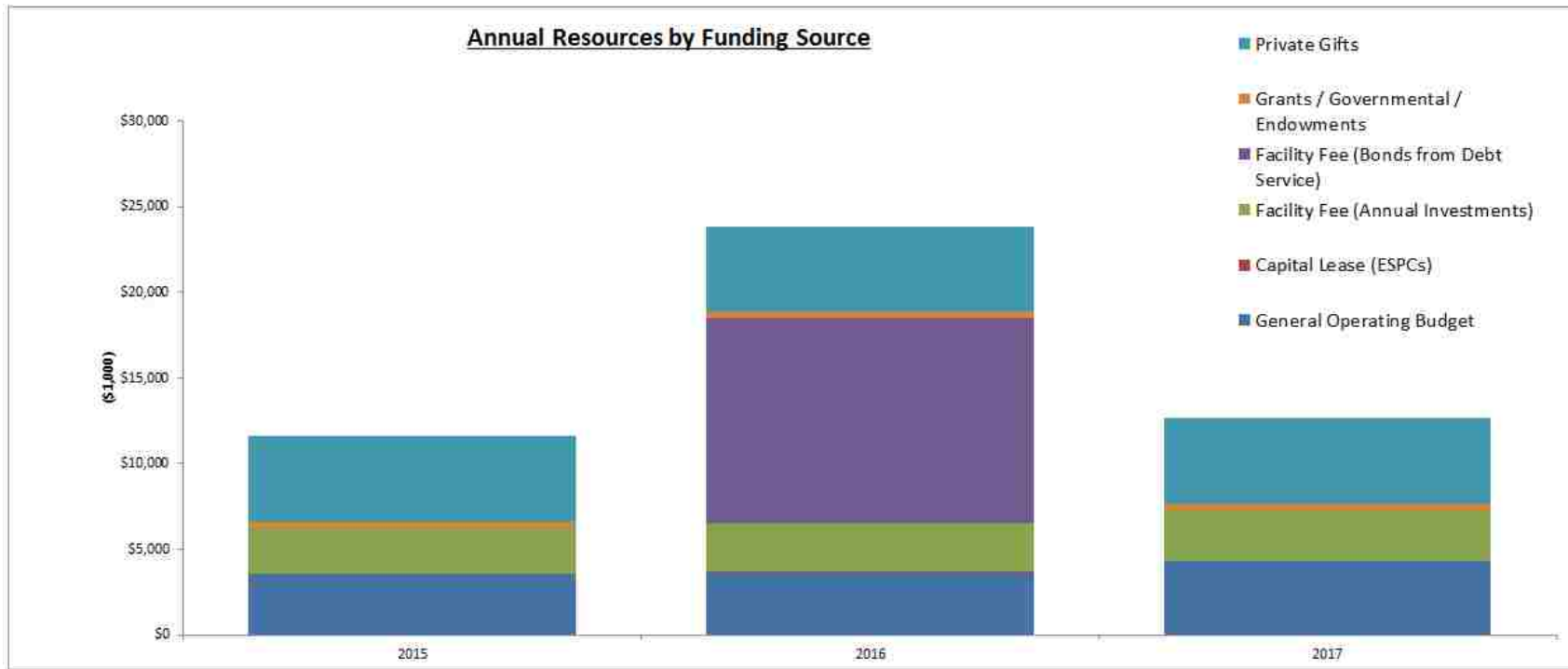
A.12 Cumulative resources by budget category

This figure shows the cumulative resources by budget category for the 3 years in the Facility Renewal and Stewardship Plan. As we can see from the figure below, there is a budget spike in 2016, which can be explained by the \$ 12 million bond issue that will be happening on 2016. The remaining categories remain fairly stable through the planning horizon. The bond issue gives the Facilities Management Office the ability to fund additional construction and projects because of the increased budget. The decision of whether to issue a bond or not for a given year is determined by the FAMA stakeholders, with the Board of Trustees approval.



A.13 Piece Chart for Budget Categories

This figure shows a different way of illustrating the different budget categories. As we can see, the majority of the budget comes from private gifts. This can be explained due to the fund raising campaign that the University of Arkansas has been focusing on for the last years. The facilities bonds are another resource that can be significant, especially if bonds are issued over the planning horizon. It is important to highlight the fact that the Facilities Fee (Annual Investments) category is the only one that has a constant source of income (supported by the Facilities Fee). The remaining categories are usually variable and can vary significantly over the years.



A.14 Total Resources by budget category

The figure is just another representation of how the Strategic Planning Tool allows the stakeholders to visualize the budget by year.

We can see the same spike that was mentioned on figure 8.12 as a consequence of the bond issue that is expected to take place in 2016.

VZ

BUILDING_CODE	BUILDING_DESC	MEETING_HOURS	DAILY_AVG_PER_ROOM	AVG_ROOM_UTILIZATION	AVG_SEAT_UTILIZATION	TOTAL_ROOMS	ROOM_DAYS	ROOM_HOURS	ROOM_CAPACITY	TOTAL_CLASSES	MEETINGS	MEETING_HOURS	CONTACT_HOURS	MATCH_ROOM	PARTIAL_MATCH	NOT_PREFERRED_LABEL	NO_PREFERENCE	FCI_Rank	%_Pref
ASTC	ABERNATHY AGRISCIENCE AND TECHNOLOGY CENTER	18	1.8	20.00%	49.00%	2	10	90	2925	8	13	18	258.7	0	18	0	0	B	0
ASUP	ACADEMIC SUPPORT BUILDING	11.2	1.1	12.50%	60.60%	2	10	90	1710	7	7	11.2	128.7	0	9.2	2	0	C	0
AFSL	AGRICULTURAL, FOOD AND LIFE SCIENCES BUILDING	31.9	3.2	35.50%	60.80%	2	10	90	3060	14	22	31.9	793.4	0	31.9	0	0	A	0
AGRX	AGRICULTURE ANNEX BUILDING	27.8	2.8	31.00%	68.80%	2	10	90	3195	10	30	27.8	700.6	0	2.5	25.3	0	B	0
AGRI	AGRICULTURE BUILDING	119.4	4	44.30%	75.00%	6	30	270	7875	53	109	119.4	2663.4	71.8	40.1	7.5	0	A	0.60134
ARKU	ARKANSAS UNION	25	5	55.60%	69.30%	1	5	45	11115	11	25	25	4343.2	22.5	2.5	0	0	A	0.9
ARMY	ARMY ROTC BUILDING	12.5	0.8	9.30%	55.50%	3	15	135	4275	8	8	12.5	227.7	0	10.5	2	0	A	0
BAND	BAND BUILDING (LEWIS E. EPLEY)	29.1	2.9	32.40%	32.00%	2	10	90	19350	15	30	29.1	2240.5	9.2	17.4	2.5	0	A	0.31615
BELL	BELL ENGINEERING	305.7	3.8	42.50%	63.50%	16	80	720	39375	145	280	305.7	12420	156.2	140.6	9	0	A	0.51096
MUSC	BILLINGSLEY MUSIC BUILDING	90.9	1.8	20.20%	41.20%	10	50	450	11835	49	103	90.9	1774.9	59.7	16.2	6.7	8.3	A	0.65677
WCOB	BUSINESS BUILDING	647.7	5	55.40%	59.70%	26	130	1170	56295	293	619	647.7	2526.2	507.4	123.6	0	16.7	A	0.78339
CARN	CARNAL HALL	3.8	0.8	8.50%	84.40%	1	5	45	1440	1	2	3.8	103.5	0	3.8	0	0	C	0
CERM	CERAMIC STUDIO	11	1.1	12.20%	41.70%	2	10	90	1350	2	4	11	137.5	0	5.5	5.5	0	A	0
CHEM	CHEMISTRY BUILDING	95.1	6.3	70.40%	70.50%	3	15	135	13275	41	101	95.1	7112.9	90.1	5	0	0	C	0.94742
ENGR	ENGINEERING HALL	112.7	4.5	50.10%	58.10%	5	25	225	11655	62	109	112.7	3474.6	42.7	55.6	14.4	0	A	0.37888
ECHP	EPLEY CENTER FOR HEALTH PROFESSIONS	74.7	3	33.20%	50.60%	5	25	225	11115	42	46	74.7	2368	69.2	4.3	1.3	0	B	0.92637
FNAR	FINE ARTS CENTER	248.8	3.3	36.90%	48.70%	15	75	675	31230	64	136	248.8	7515	23.3	183.5	39.5	2.5	A	0.09365
FDSC	FOOD SCIENCE BUILDING (HORTICULTURE)	27.1	2.7	30.10%	60.50%	2	10	90	3240	12	20	27.1	534.8	0	24.6	2.5	0	B	0
FUTR	FUTRALL HALL	50	5	55.60%	93.80%	2	10	90	1440	60	60	50	750	0	0	0	50	B	0
GRAD	GRADUATE EDUCATION BUILDING	283.7	3.5	39.40%	58.00%	16	80	720	27440	123	221	283.7	7887.5	204.5	12.5	66.7	0	A	0.72083
GREG	GREGSON HALL	108.3	5.4	60.20%	87.50%	4	20	180	3105	129	130	108.3	1624.9	0	0	0	108.3	B	0
ROSE	HARRY R. ROSEN ALTERNATIVE PEST CONTROL CENTER	16	3.2	35.60%	52.80%	1	5	45	1080	9	12	16	200.5	0	11	5	0	A	0
HPER	HEALTH, PHYSICAL ED. AND RECREATION (HPER)	195.1	2.8	31.00%	43.70%	15	75	675	113220	84	180	198.9	6503.3	111.7	77.8	9.4	0	A	0.56159
HILL	HILLSIDE AUDITORIUM	60.8	6.1	67.60%	77.80%	2	10	90	33300	25	63	60.8	16900	52.5	5.8	2.5	0	A	0.86349
HOEC	HOME ECONOMICS	209	3.5	38.70%	61.50%	12	60	540	20070	81	174	209	6401.3	117.3	88.5	3.2	0	C	0.56124
JBHT	JB HUNT TRANSPORT, INC. CENTER FOR ACADEMIC EXCELLENCE	319	4	44.30%	62.50%	16	80	720	36900	147	328	319	12601	223.2	93.2	2.5	0	A	0.69969

A.15 Snapshot of X25 and FCA Database Table (Data Source Table)

This figure illustrates a snapshot of what the source data for the project assessment looks like. This data combines the X25 utilization rates, the scheduling preference percentages, and the FCI ranking into one single source for the tool to gather its information from.

After the process is executed, the respective score for each one of the five value measures is retrieved from this table, as well as automatically populating the project assessment, calculating the value of each one of the alternatives.