Warehouse Design for POLY GAIT

A Senior Project

presented to

the Faculty of the Industrial Engineering Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Industrial Engineering Bachelor of Science

by

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Table of Contents

Introduction and Background

This project will involve designing a building for Dr. Tali Freed and POLY GAIT. The idea came from Professor Freed. She wants a warehouse to be built by the Radio-Frequency Identification (RFID) lab in the hangar (building 4). The warehouse is intended to provide an area to do research on RFID technology, as well as a location for the development of robotics technology in the Lab for Autonomous and Intelligent Robotics (LAIR). Professor Freed hopes that someday POLY GAIT can work with LAIR to create their own version of the automatic storage and retrieval systems (AS/RS). This project will involve designing the layout of the warehouse using ideas from IE like facilities design, cost analysis, and human factors. Also a simulation will be created to test for the best layout possible. There are two proposed sizes for the building. The first is a 25' by 22' design that will only cover the existing concrete on the northwest side of the hanger. This would be the most cost efficient as it requires less building material but since it is a smaller building it might hinder the research. The second option is a 25' by 63' building that would extend past the concrete area to match the edge of the hangar. This would provide a lot larger warehouse to work with being almost three times the size. A small tree would have to be removed for this option. Further cost analysis will be needed to see which option is better. Professor Freed conveyed to me that one of the most important factors in the warehouse design will be cost.

This building is important for the newer RFID technology because it will allow real data to be gathered instead of just theory. It will also provide a much larger space for the RFID Technology Alliance to work and expand their knowledge of RFID.

Deliverables

- Digital building drawings
- A 3D model of the warehouse
- A simulation model of operations
- An excel spreadsheet of the cost analysis
- Final report with recommendations
- PowerPoint presentation to convey my recommendations

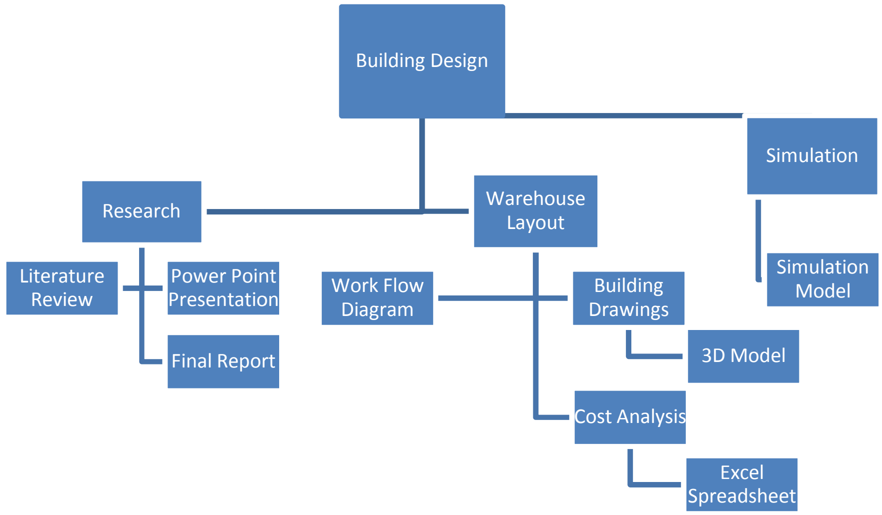
Scope

The scope of this project will be up to what the deliverables are and will not include raising funds or actually building the warehouse. Looking for grants and/or funds and filing the building permit application are things that can be the done by the RFID club should they choose to accept my building design proposal.

Relevant Coursework

This warehouse will be using Project Management (IME 303) to help with the organization of this project. Knowledge gained from Facilities Design (IME 443) will be used to design the warehouse and create building drawings and a 3D model. The cost analysis will be from a combination of Industrial Cost and Controls (IME 239) and Engineering Economics (314). Simulation will be from the Simulation class (IME 420). And all the human factors considerations will be from Human Factors Engineering (IME 319).

Work Breakdown Structure



Priority Matrix	Time	Performance	Cost
Constraint	X		
Enhance			X
Accept		X	

As discussed before, the priority matrix shows that enhancing the cost is the most important element to Professor Freed. Time is a constraint for me but not necessarily for the entire project (including actual construction of the building); therefore the performance must be accepted.

The following Literature Review provides examples and guidelines on planning to design a warehouse from previously designed warehouses. It also gives some background on the use of simulation in warehouses as well as some background on automated storage and retrieval systems (AS/RS).

Literature Review

Figures indicate the operating cost of warehouses represent 22% of logistics costs in the US (Establish, 2005), while they represent 25% of logistic costs in Europe (ELA/AT Kearney, 2004). Given this information, it is plain to see these make up a large portion of the cost of any large product based company. Therefore, it would make sense to try and reduce the costs as much as possible. There are many ways to do this, but this paper will be focusing on facilities design and simulation. There are many other factors that contribute to the cost and efficiency of a warehouse, such as inventory control and human factors.

Facilities Design

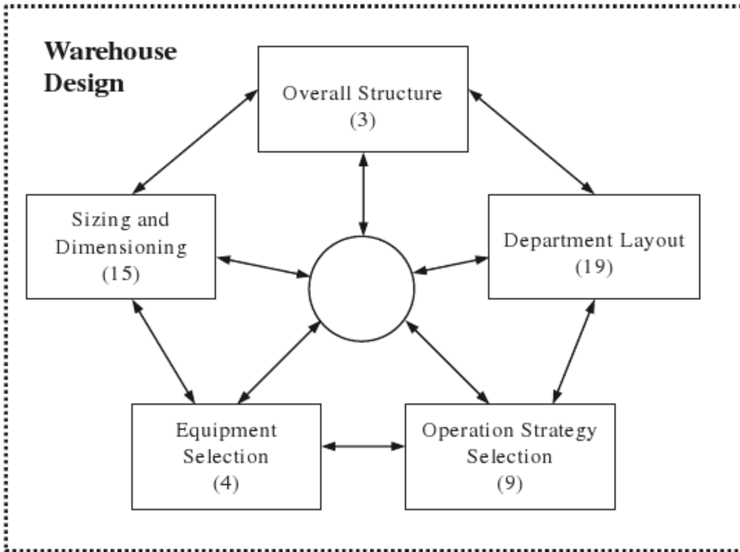
Facilities or warehouse design depends heavily upon many factors including, but not limited to, space availability, company size, available funds, product production rate, customer demand, and company growth. A large portion of warehouses provide next-day or even same-day lead time, therefore these companies need to achieve high reliability with reasonable speed and low product damage (Baker, 2004). Despite the importance of cost to all companies, there are very few academic journals written about warehouse design and the ones that have been written are only general outlines (Baker, 2009). Since there are only general layouts, most

warehouse designers have taken a more custom approach (Oxley, 1994). This makes sense because each company has vastly different circumstances and requirements for their warehouse.

Over the years there has been an evolution in warehouses design starting with Heskett (1973) who had a simple process of first, determine warehouse requirements, then design material handling systems and facility design, and lastly to develop the facilities layout. The development of the steps taken to designing a warehouse can be seen in Table 1a and Table 1b in the appendix (Baker, 2009). These are broken into two tables to show 1973 up to 2000 and then 2000 till 2006. After analyzing the two tables Baker (2009) was able to create a step by step process of his own to designing a warehouse. These are as follows:

1. Define system requirement
2. Define and obtain data
3. Analyze data
4. Establish unit loads to be used
5. Determine operating procedures and methods
6. Consider possible equipment types and characteristics
7. Calculate equipment capacities and quantities
8. Define services and ancillary operations
9. Prepare possible layouts
10. Evaluate and assess
11. Identify the preferred design

Even though there is a quite detailed way in planning a warehouse, the actual warehouse can be broken down into five distinct categories or areas. These consist of the



Overall Structure, Sizing and Dimensioning, Department Layout, Equipment Selection, and Operation Strategy Selection (Jinxiang et al., 2007). They are all connected to each other and thus need to be designed as seen in

Figure 1. The overall structure (or conceptual design) of a warehouse determines the flow of the warehouse. It determines the functional departments, such as determining how many storage departments there are and what technologies they use. It also determines how the orders are going to be assembled and moved. Sizing and dimensioning is another important element, but is heavily dependent on factors such as cost of construction, technology used, equipment need, inventory size, and customer base. Therefore it is determined on a case by case basis. Department layout involves deciding where the products are going to be stored in the warehouse. It also determines where such things as the aisle location, aisle width and depth, number of aisles, door location and so on and so forth. These all contribute to material cost, travel time, storage capacity, space utilization and equipment utilization. Equipment selection is dependent on what type of storage and retrieval systems that should be used. This also depends on the space available and on a cost –productivity analysis called the hierarchy of productivity ratios (Cox, 1986). The operation strategy has two major processes: the storage and order picking strategies.

Simulation

Simulation is a critical step in analyzing any warehouse design. Simulation is used to imitate real processes rather than averaging values and evaluating these numerical values within several mathematical equations. It is used to predict the performance of a plan to compare alternative solution.

Kempfer (2005) argues that there are five main reasons to use warehouse simulation. The first is proof of concept. Once a simulation is designed, it is easy to play “what if” games and plug in different variables such as product demand or even labor hours. It will show flaws in the design that only appear when the system is used. The second is executive and employee buy-in. Simulation offers a visual aid when trying to convince the boss or fellow employees that something needs to be changed in the current plans. At this point it is stressed that the data collected to use simulation is extremely important in creating an accurate simulation. The third is to optimize operational and business rules. The fourth is to optimize the control system. This means that sometimes the flaw that simulation actually discovers is sometimes the control system or operational procedures. The fifth is to simply revalidate the design. After the simulation runs smoothly then it is time to build. And you can also come back to it after the warehouse is built to simulate any further changes that were unforeseen, such as necessary warehouse expansion.

Simulation is a necessity when comparing different automated storage and retrieval systems (AS/RS). They are too expensive to physically test and come in many different shapes

and sizes to just guess on which one works best. The most important factors of the AS/R are system configuration and the policies used for storing and retrieving items to and from the warehouse (Sabah, 1994).

Although AS/RS are the current dominated system used there is a new up and coming technology called autonomous vehicle storage and retrieval systems (AVS/RS) that is now more common in Europe but has yet to appear in the US (Sunderesh, 2008). Since 1994 the AVS/RS has been applied successfully in 35 installations in 8 different countries (Sunderesh, 2008)

Human Factors

A small but important part of facilities design, when associated with human factors, is that of lighting. Working with adequate lighting can have a significant impact upon productivity. Ideal conditions would have sunlight be the only source of light, shining whenever the warehouse needed light. This would create more than sufficient light with practically no cost. This, however, is not possible. Instead we can consider such things as skylights and windows high up in the warehouse to provide the most light (Reinhart, 2006).

Other things that should be considered when designing a warehouse, in which people will be conducting work, are safety factors, such as a sprinkler system and smoke venting in case of a fire. He (2002) has produced a detailed approach in determining all the factors necessary in designing a smoke venting and fire safety system in a warehouse with advanced computer simulation of fire growth and smoke spread.

There is also a need for considering how employees will be moving equipment for proper set-up of the facilities or warehouse. For instance, are the systems going to be moved by hand jacks, and dollies, or is something more heavy duty going to be needed such as a forklift? These are all questions that need to be thought of when designing this warehouse.

Method

The following has already been mentioned above in the literature review section but since these 5 steps are what was used in planning the design of the warehouse then it is logical to use them as a guideline for this section.

Overall Structure

As mentioned before, the overall structure determines the flow and the functional departments of the warehouse. Since the warehouse design currently being discussed is going to be an experimental warehouse the flow of the warehouse should be a simple as possible. A simple U-shape would be best, in which orders come in, go around the outside of the warehouse, and then go out.

Also in the overall structure it is necessary to determine what departments are going to be in the warehouse as well as where they are going to be within the warehouse. This includes offices, shipping, receiving, storage, and even where the restrooms are. Again, since this warehouse design is going to be an experimental warehouse, not all these departments are needed. There is really only the need for two departments: a storage area, and a shipping/receiving area. Their sizes and layouts are decided in the department layout below.

Sizing & Dimensioning

Usually the size of the warehouse is dependent on how big the company is and the cost of building the warehouse, but since this warehouse design is going to be used for experimentation the main factor is the area POLY GAIT had to work with. The area designated for this warehouse is behind the Hanger (bldg 4) at Cal Poly. It is next to an area being used by the Lab for Autonomous and Intelligent Robotics (LAIR) and is currently being used for storage for various parts. The maximum the warehouse can be is 25 feet wide by 63 feet long. Any bigger and it would be too close to the edge of the hill to be able to lay a foundation. The smaller proposed size would cover the area that is already

fenced and would be 25 feet wide by 22 feet long. Any smaller and the warehouse would not be large enough to be able to conduct any accurate experimentation in.

For this project the two above sizes were used to model layout proposals. It is possible to have a building size in between but by picking the largest and the smallest sizes the largest and smallest cost in the cost analysis is captured. It is also worth noting that since Dr. Tali Freed requested the warehouse be as least expensive as possible the smallest warehouse that meets all the requirements will most likely be the chosen design.

Operating Strategy

The two major processes for operation strategy are storage and order picking. This is essentially the main reason why this project focused on designing this warehouse. It will be testing the use of AS/R systems in tandem with RFID technology. POLY GAIT will be testing to see exactly how the two technologies will work together to optimize the warehouse space and workers present. Should they chose, they can also compare different AS/R systems to see which works better with RFID technology as well as which ones are more economically friendly.

Equipment Selection

The selection of the equipment is largely based off the AS/R system selected in the operating strategy. As a default for this warehouse, regular industrial storage racks are used in the layout design to represent the storage area. The real way items would be stored is directly related to how the AS/R system being used picks product of the shelf, or how it brings the product to the next station.

The equipment selection also has a considerable impact on how the foundation is made because forklifts and other industrial equipment create a large point load on the ground. If this isn't accounted for then the foundation might crack and chip and cause costly repairs. Since this warehouse will be small we will not need any large industrial equipment to move our product. Smaller equipment such as hand trucks and pallet jacks may be needed to set up the warehouse up before AS/R system can run or if a different AS/R system is going to be tested.

Department Layout

The department layout is the main focus of this project. Department layout dictates where everything is in the warehouse. It determines where doors, desks, windows, storage racks and various other things are located. A variety of different layouts options with different combinations of storage rack orientation and department sizes were created. They can be seen in Figure 2.

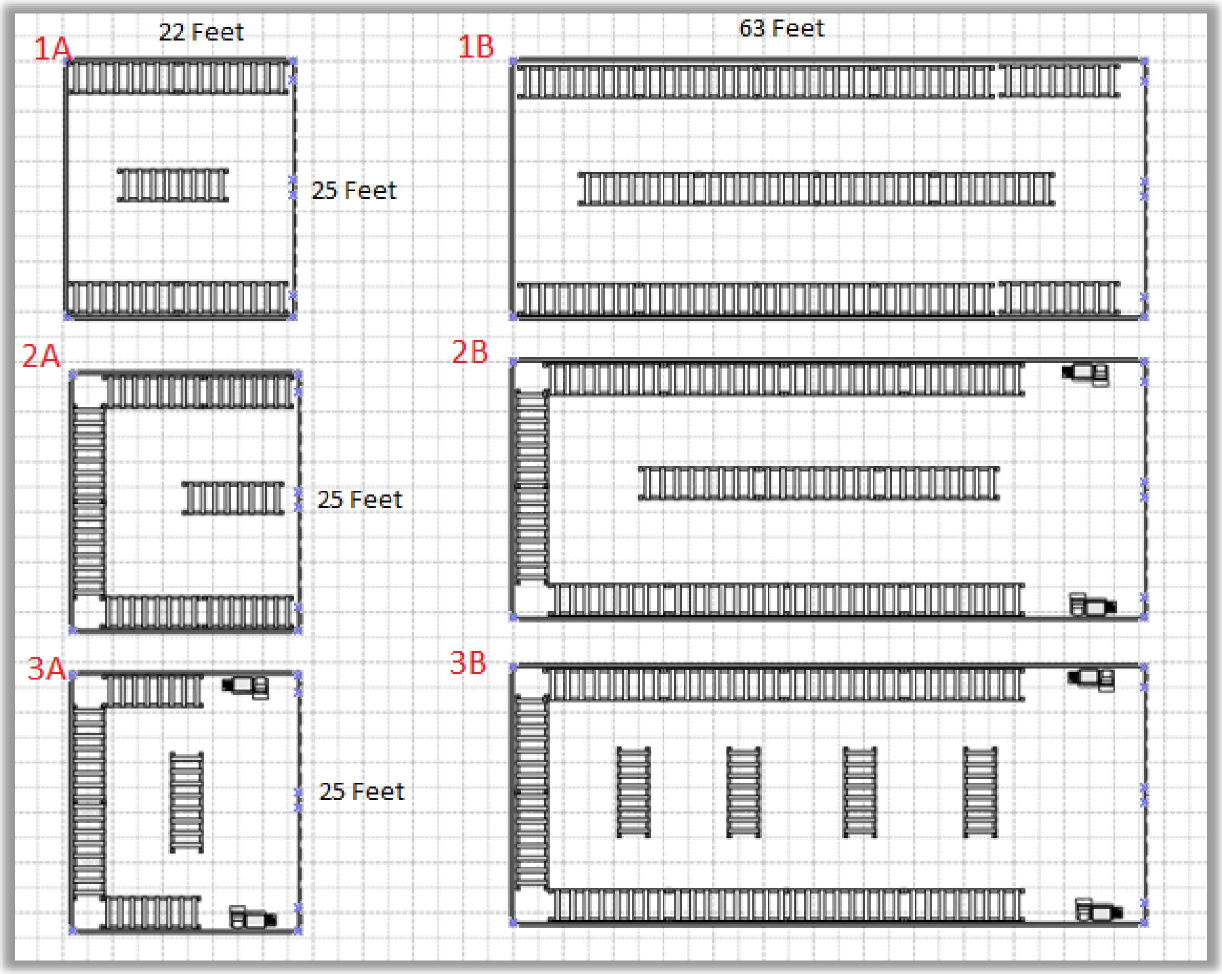


Figure 2 – Layout Proposals

Layout proposals 1A, 1B, and 2A all have maximum rack space with very little room for shipping and receiving while the others have some space set up for a dock area. After these layout options were reviewed with the customer Dr. Tali Freed, she reiterated that her main interest in this project was to create a warehouse design that would suit the needs of POLY GAIT and be as inexpensive as possible. She thought the 3A option would be the best way to accomplish this. Therefore, that option was selected and detail was added. The results of this are shown in Figure 3.

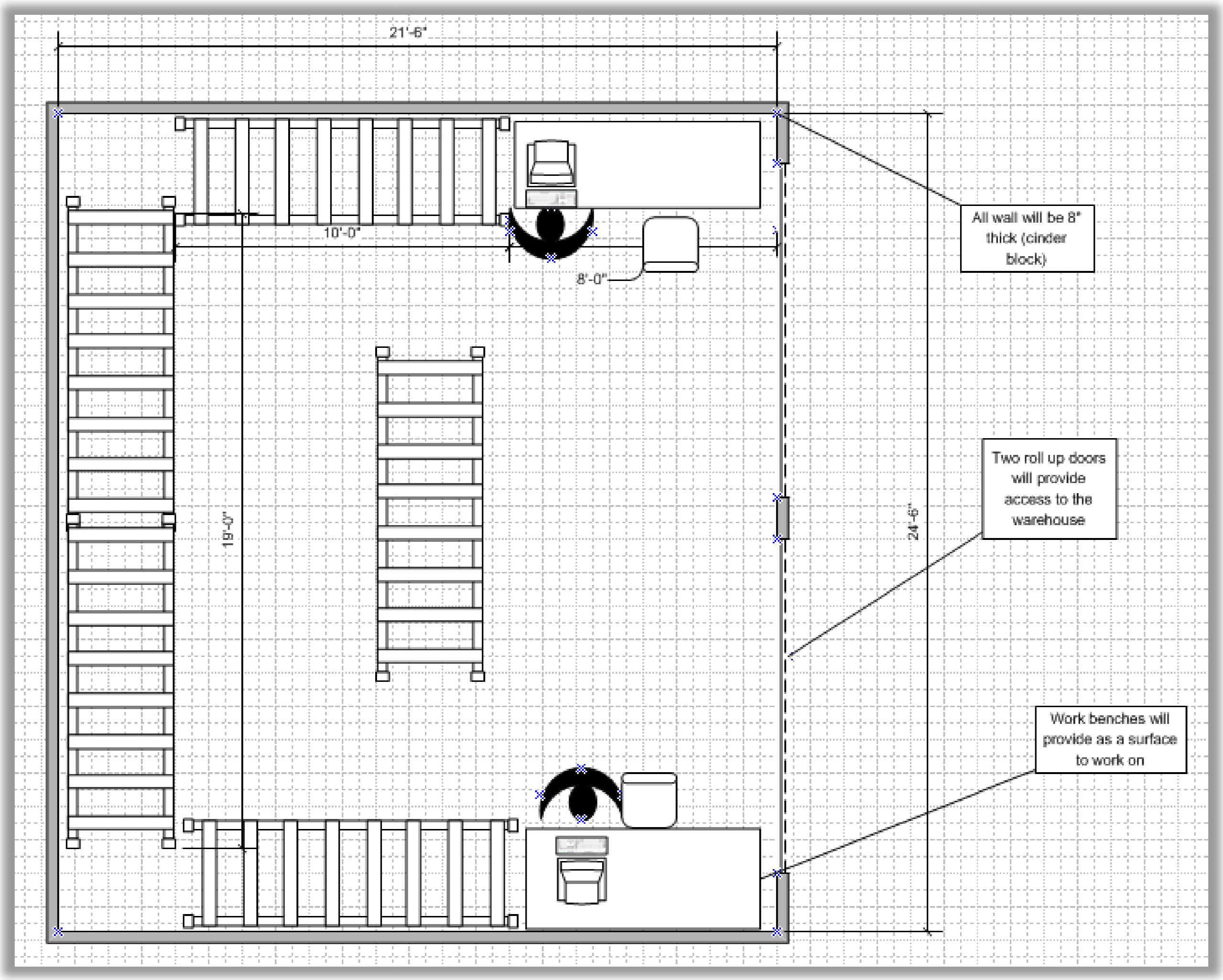


Figure 3 – Layout 3A

The main takeaways from this are the following:

The smaller 25’x22’ size warehouse is preferred.

The doors will be roll-up doors located on the north east side of the building.

The shipping and receiving areas will be directly next to the doors and take up about 8 feet from the door. The rest of the warehouse will be used for storage.

Since the basic warehouse shell has been chosen then further analysis can be done such as simulation and cost analysis.

KIVA System

Although there hasn't been a concrete decision as to which AS/R system will be used, Dr. Tali Freed seemed interested in the KIVA Systems. As seen in Figure 4 the KIVA System is basically a little robot that rolls around on the floor. Once it knows which item it needs to get it will roll under the small storage rack that has the item needed and then lift the entire storage rack and bring it to the worker at the end of the warehouse so they can take off what is required for the order. Then the robot will take it back into the storage area but not necessarily the same spot. Once it puts the storage rack down it is sent another item to retrieve and goes to that small storage rack. An example of what a KIVA System layout would look like can be seen in Figure 9 in the appendix.

Figure 4 – KIVA System

If this were the model selected then no industrial storage racks would be needed. Instead the warehouse would have a bunch of small storage racks that would be about 3 feet by 3 feet. The 3 by 3 storage racks are an estimate of what KIVA uses since they don't provide any detailed information unless you are a customer. One thing POLY GAIT could test is to see if this is a better use of space in a warehouse by comparing this method to standard industrial racks.

Simulation

As a very wise simulation professor once said "All simulations are wrong, but some are useful." When a simulation is being made, the easiest way to start is with the systems bare minimum requirements to define it as a system. From this more detail is added until it becomes useful. However, adding more detail does not always increase the utility of the simulation. The benefit of the detail starts to have a negative impact on the simulation as the Laffer curve shows in Figure 5.

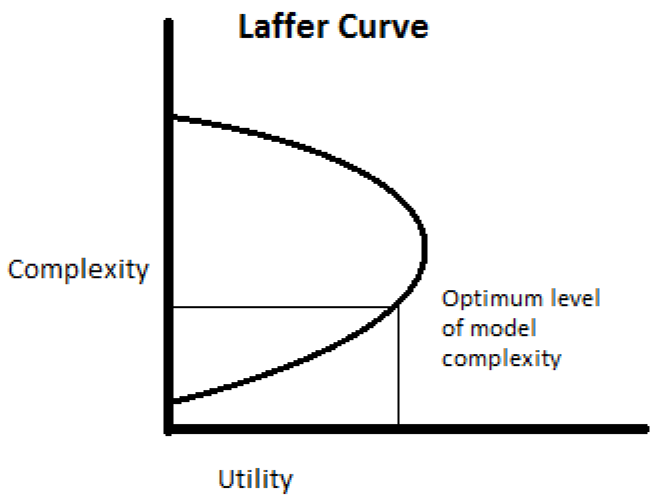


Figure 5 – Laffer Curve

One of the hardest parts of creating a simulation is collecting data. Unfortunately, since the warehouse is not created yet, there is not any real data to use in this simulation model. Instead basic, easily changeable numbers are used. These numbers will need to be changed out once real simulation data is collected. Since time is being used to determine when events happen in my simulation model, this makes it a dynamic simulation.

Logical Model

The first step in creating a simulation is to create a logical model. The one for this warehouse design can be seen in Figure 6.

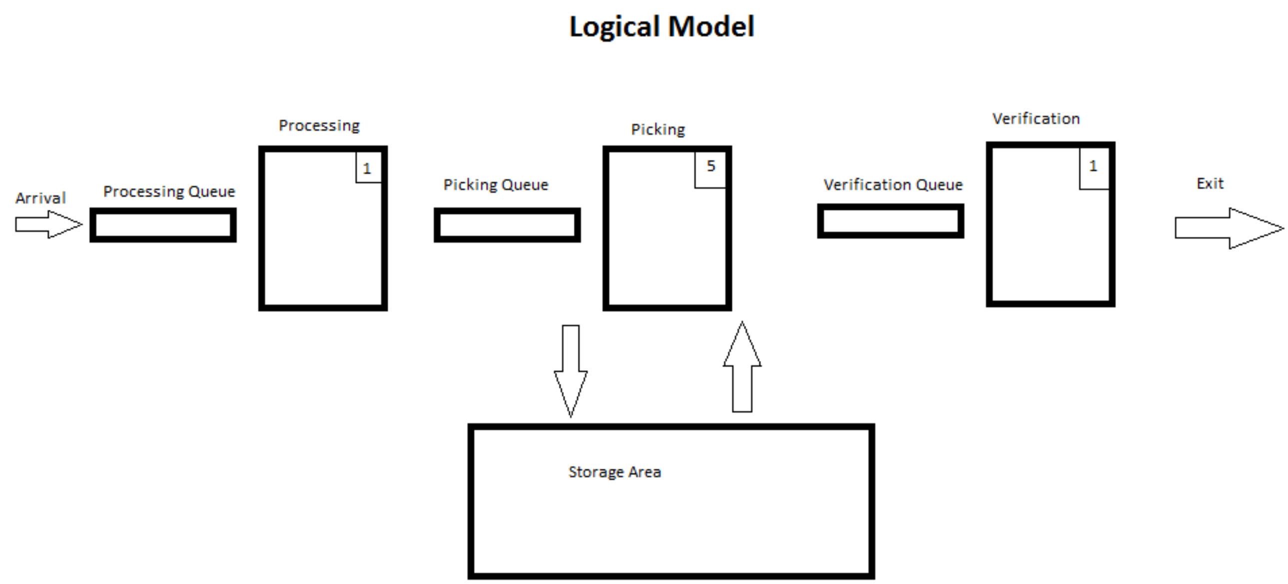


Figure 6 – Logical Model

The orders first arrive at the processing queue. Once the worker at the computer is ready, they are processed and moved in the picking queue. When an available picker is ready it will go to a different shelf in the storage area depending on what items are needed to fill the order. Once the picker has what it needs it will go to the verifications queue. Here the worker makes sure the picker got the right item. Also the worker at the verification places the item in a box and attaches a shipping label and puts it on the truck which in this simulation is the same as exiting the system.

The following are a list of how the logical model was implemented in ProModel.

Locations

- Processing queue
- Processing
- Picking queue
- Picking
- Verification queue
- Verification and packing

Entities

- Orders

- Pickers

Activities

- Arrivals

Resources

- Pickers

Assumptions

- All orders are picked with one picker
- The pickers require no downtime
- There are no space constraints
- Data times are estimated

Cost Analysis

The cost analysis is a major part of any construction project. An excel spreadsheet was used in the cost analysis for this warehouse design. An example of the front page of the excel spreadsheet can be seen in Figure 7 below. This section describes what was used in the cost estimation of the warehouse.

Building Size			Shorter Option		Longer Option	
		Wall 2	22	Feet or	63	Feet
	Wall 1					
25	Feet		12	Feet =	Building height	
		Wall 3				

Estimation by Square Foot		**Total Cost**
Shorter Option	Concrete Block / Bearing Walls	$ 41,151.00
	Concrete Block / Steel Frame	$ 42,966.00
	Tiltup Concrete Panels / Steel Frame	$ 42,966.00
Longer Option	Concrete Block / Bearing Walls	$117,841.50
	Concrete Block / Steel Frame	$123,039.00
	Tiltup Concrete Panels / Steel Frame	$126,551.25
Estimation by bottom up calculations		
Shorter Option	Concrete Block / Bearing Walls	$ 49,417.69
Longer Option	Concrete Block / Bearing Walls	$133,295.57

Cost Works is an online tool provided by RSMeans that has cost data and estimating tools. It can be used to estimate the cost of anything that has to do with construction. It can estimate the cost of houses, business offices, or in my case, warehouses. It allows you to select the size, type of labor used, stories, story height, and much more. Then it gives a national estimate that is an average of all warehouses built in the US that are similar to the options selected. That national average is then multiplied by your local multiplier based on what city you are building in. By using this tool it was easy to compare the cost of several different building materials. The cheapest as seen in Table 2 is concrete blocks with bearing walls.

Tilt up walls would not be very practical due to the location of the warehouse. Areas on all sides of the warehouse are needed in order to build the walls. The difference between concrete blocks with load a steel frame and concrete blocks with bearing walls is that the steel frame takes the weight of the

walls where as the load bearing walls carry all their own weight. Since this building won't be very tall (between 10 and 14 feet) the weight of the walls isn't very much. Building for earthquakes can still be done during the construction phase by adding a reinforcing cage like assembly every 7-8 feet to eliminate the concrete blocks from crumbling when the building is hit by seismic waves. Also the doors and windows would need to be reinforced. This is part of the miscellaneous cost that was added and is talked about in the next paragraph.

In order to verify this way of estimating the cost of the warehouse a "bottom up" estimate was calculated and compared to the cheapest method: concrete blocks with load bearing walls. This was done by calculating the cost and amount needed of the concrete blocks, mortar, rebar, foundation, equipment, and roofing. As a general rule, noted from several estimation web sites, labor usually cost about the same as materials in any type of construction project so once the total cost was calculated for the materials it was just doubled to get the overall price of construction (details can be seen in Table 3 and 4 in the appendix). This estimate came out slightly higher than RSMeans estimate but it is still in the same ballpark as seen in Table 2. When estimating for the bottom up analysis the 'worst case' scenario was always used and an extra 5% was added for miscellaneous costs which could also add to why the bottom up estimate was higher.

Results and Conclusions

As shown by this report, the optimal choice of warehouse size would be the smaller warehouse. From the beginning it obvious that it would cost less and take less time to build but since it meets all the customers' requirements then it should be chosen. It is going to cost from around 40 to 50 thousand dollars to build. Dr. Tali Freed and POLY GAIT now have a ballpark idea on how much money they would need to raise via grants or company sponsors in order to have this warehouse built.

There were two main points of this project; the first was to apply the knowledge gained from obtaining and Industrial Engineering degree at Cal Poly, the second was to provide Dr. Tali Freed and POLY GAIT with a cost estimate on how much a warehouse would cost and a rough draft of what it might look like when they decide to have it built. Both of these points have been covered in this report.

A future addition to this project could be done once the warehouse is built and real data can be collected. Once this happens, it can be put into the simulation model and more detail can be added to the simulation model if necessary. This would allow POLY GAIT to simulate thousands of hours by only having to physically do a few.

Appendix

Table 1a
Warehouse design steps in the literature (1973-2000)

Heskett et al. 1973	Apple 1977	Firth et al. 1988	Hatton 1990	Mulcahy 1994	Oxley 1994	Govindaraj et al. 2000
		Identify the warehouse functions	Determine the task (inc. data collection)		Define system requirements	
Determine warehouse requirements	Procure data	Gather data and make projections	Analyse product quantity	Collect data	Define and obtain data	Assemble and analyse data
	Analyse data		Analyse product movement	Analyse data	Analyse data	
					Establish unit loads to be used	
Design material handling systems and facility design	Design processes	Develop alternative methods	Develop alternative concepts	Establish design year parameters	Determine operating procedures and methods	Determine functional requirements
	Plan material flow pattern	Combine functional alternatives into single system		Consider alternative material handling equipment and concepts	Consider equipment types & characteristics	Make high-level ("architecture") decisions
	Calculate equipment requirements				Calculate equipment capacities and quantities	
	Plan individual work areas			Identify administrative function areas	Define services & ancillary operations	
Develop the facility layout	Select material handling equipment			Develop alternative layouts	Prepare possible layouts	
	Determine storage requirements		Develop the management system (methods, procedures and systems)		Evaluate and assess	Undertake detailed system specification and optimization
	Plan service and auxiliary activities	Select the total system			Identify the preferred design	Reiterate above steps
	Determine space requirements					
	Allocate activity areas to total space					
	Construct the master layout					

Table 1b
Warehouse design steps in the literature (2000-2006)

Rouwenhorst et al. 2000	Rowley 2000	Rushton et al. 2000	Bodner et al. 2002	Hassan 2002	Waters 2003	Rushton et al. 2006
Define concept	Define system requirement and design constraints	Define system requirements and design constraints		Specify type and purpose of warehouse		Define business requirements and design constraints
Acquire data	Define and obtain relevant data	Define and obtain data	Assemble data	Forecast and analyse expected demand	Estimate future demand	Define and obtain data
	Analyse data	Analyse data	Undertake data profiling	Establish operating policies	Forecast movements through warehouse	Formulate a planning base
	Establish unit loads to be used	Establish unit loads to be used		Determine inventory levels		Define the operational principles
Produce functional specification	Postulate operating procedures and systems	Postulate basic operations and methods	Determine high-level functionalities	Form classes (of products)	Compare available handling equipment	Evaluate equipment types
Produce technical specification	Consider equipment types and characteristics	Consider possible equipment types	Produce high-level specification ("architecture")	Departmentalize (into areas) and establish general layout	Calculate the space needed for storage and movement	Prepare internal and external layouts
Select the means and equipment	Calculate equipment quantities	Calculate equipment quantities		Partition into storage areas	Identify which materials should be close to each other	Draw up high-level procedures and IS requirements
	Define other facilities and services	Calculate staffing levels		Design material handling, storage and sortation systems		Evaluate design flexibility
Develop layout	Draft possible layouts	Prepare possible building and site layouts		Design aisles	Develop outline plans	Calculate equipment quantities
Select planning and control policies	Select the preferred design	Evaluate the design against requirements	Undertake detailed system specification/ optimization	Determine space requirements		Calculate staffing levels
	Evaluate and assess expected performance	Identify the preferred design	Reiterate above steps	Determine input / output points	Finalise plan	Calculate capital and operating costs
	Conduct computer simulations			Determine docks		Evaluate the design against requirements
				Determine the storage arrangement		Finalise the preferred design
				Form picking zones		

Table 3 - Bottom Up Estimate

	Bottom up calculations				
		Wall 2	22	Feet(1) or	63 (2) Feet
	Wall 1				
25	Feet		12	Feet =	Building height
		Wall 3			

Total Cost	1	2	
Walls	$ 1,007.05	$ 2,197.42	
Foundation	$ 9,525.19	$ 27,276.67	
Roof	$ 5,000.00	$ 15,000.00	
Equipment	$ 3,000.00	$ 9,000.00	
Furnishing	$ 5,000.00	$ 10,000.00	
Labor	$23,532.23	$ 63,474.08	(x2)
Misc.	$ 2,353.22	$ 6,347.41	5%
Total	$49,417.69	$ 133,295.57	

		Building size							
		Length	Width	Height	Building Area	Wall 1 Area	Wall 2 Area	Wall 3 Area	Toatal Wall Area
1	Feet	25	22	12	550	300	264	264	828
1	Inches	300	264	144	79200	43200	38016	38016	119232
2	Feet	25	63	12	1575	300	756	756	1812
2	Inches	300	756	144	226800	43200	108864	108864	260928

		Blocks needed		
		Length	Height	Total
1	Wall 1	18.75	18	337.5
1	Wall 2	16.5	18	297
1	Wall 3	16.5	18	297
			Total	931.5
2	Wall 1	18.75	18	337.5
2	Wall 2	47.25	18	850.5
2	Wall 3	47.25	18	850.5
			Total	2038.5

	Price per Block	# Blocks	Total Cost (for blocks only)
	Home Depot Price		www.homedepot.com
1	$ 0.97	931.5	$ 903.56
2	$ 0.97	2038.5	$ 1,977.35
	Lowes		www.lowes.com
1	0.97	931.5	$ 903.56
2	0.97	2038.5	$ 1,977.35

	Total surface area		cost per foot/unit	Cost
1	828			
2	1812			
	Number of blocks needed			
1	736			
2	1610.66667			
	6% waste			
1	780.16		$ 0.97	$ 756.76
2	1707.30667		$ 0.97	$1,656.09
	Morter cost			
1	24.96512			
2	54.6338133			
	40% waste			
1	34.951168		$ 5.23	$ 182.79
2	76.4873387		$ 5.23	$ 400.03
	Spacers	ft of rebar		
1	Wall 1	162	$ 0.15	$ 24.30
1	Wall 2	144	$ 0.15	$ 21.60
1	Wall 3	144	$ 0.15	$ 21.60
2	Wall 1	162	$ 0.15	$ 24.30
2	Wall 2	390	$ 0.15	$ 58.50
2	Wall 3	390	$ 0.15	$ 58.50
			Total 1	$1,007.05
			Total 2	$2,197.42

Foundation

http://www.diychatroom.com/f19/

		Thickness	Length	Width	Total cubic in. needed	Cubic Yards	# per cubic yard	Total #'s needed	Cost per 60# bag	Total Cost
1	inches	8	300	264	633600	13.5802469	3600	48888.88889	$ 11.69	$ 9,525.19
2	inches	8	300	756	1814400	38.8888889	3600	140000	$ 11.69	$27,276.67

Table 4 - RSMeans Cost Estimation

http://www.reedconstructiondata.com/rsmeans/models/warehouse/california/san-luis-obispo/					
Cost Estimation Assumptions	Reed Construction	Our Building		Our Building	
Location	San Luis Obispo	San Luis Obispo		San Luis Obispo	
Stories	1	1		1	
Story Height	24	15-Dec		15-Dec	
Floor Area	30000	550		1575	
Labor Type	Union	Open Shop		Open Shop	
Basement Included	No	No		No	
Date Release	2008	2011		2011	
	22x25				
	Warehouse Type	Cost per sq ft (Union)	Estimated Cost (Union)	Cost per sq ft (Open Shop)	Estimated Cost (Open Shop)
	Brick with Block Back-up / Bearir	$ 96.44	$ 53,042.00	$ 88.27	$ 48,548.50
	Concrete Block / Bearing Walls	$ 81.63	$ 44,896.50	$ 74.82	$ 41,151.00
	Concrete Block / Steel Frame	$ 85.11	$ 46,810.50	$ 78.12	$ 42,966.00
	Galvanized Steel Siding / Steel F	$ 91.81	$ 50,495.50	$ 84.10	$ 46,255.00
	Metal Sandwich Panels / Steel Fr	$ 90.04	$ 49,522.00	$ 82.66	$ 45,463.00
	Tiltup Concrete Panels / Steel Fr	$ 87.29	$ 48,009.50	$ 80.35	$ 44,192.50
	63x25				
	Brick with Block Back-up / Bearir	$ 96.44	$ 151,893.00	$ 88.27	$ 139,025.25
	Concrete Block / Bearing Walls	$ 81.63	$ 128,567.25	$ 74.82	$ 117,841.50
	Concrete Block / Steel Frame	$ 85.11	$ 134,048.25	$ 78.12	$ 123,039.00
	Galvanized Steel Siding / Steel F	$ 91.81	$ 144,600.75	$ 84.10	$ 132,457.50
	Metal Sandwich Panels / Steel Fr	$ 90.04	$ 141,813.00	$ 82.66	$ 130,189.50
	Tiltup Concrete Panels / Steel Fr	$ 87.29	$ 137,481.75	$ 80.35	$ 126,551.25

Simulation

Figure 7 - Smaller Layout design

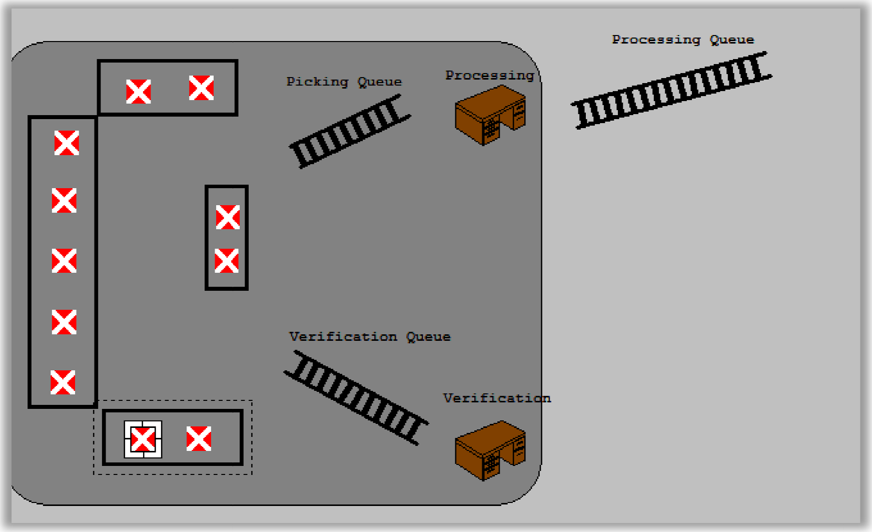


Figure 8 - Larger Layout design

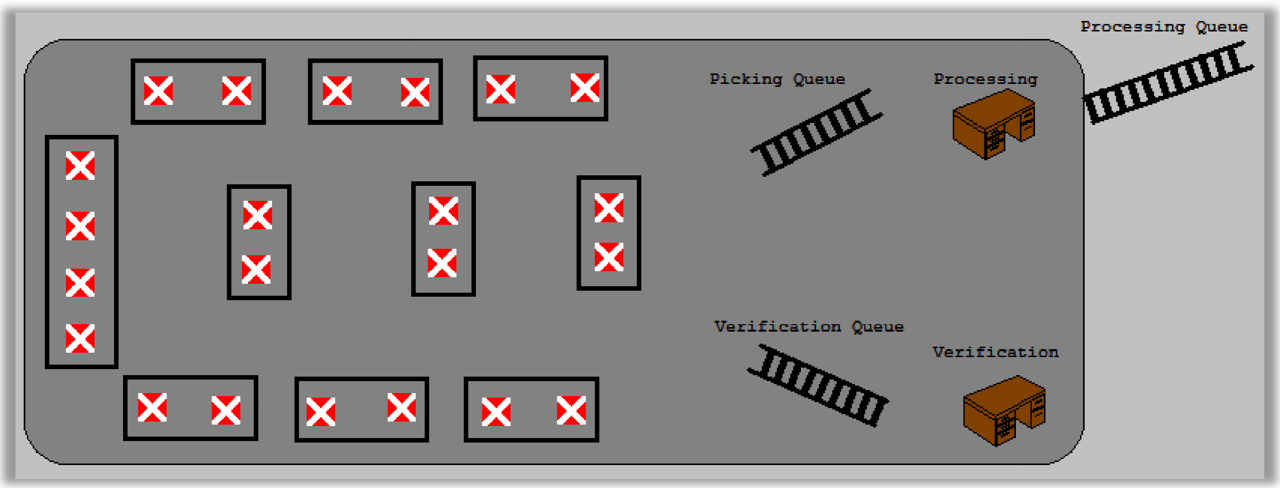
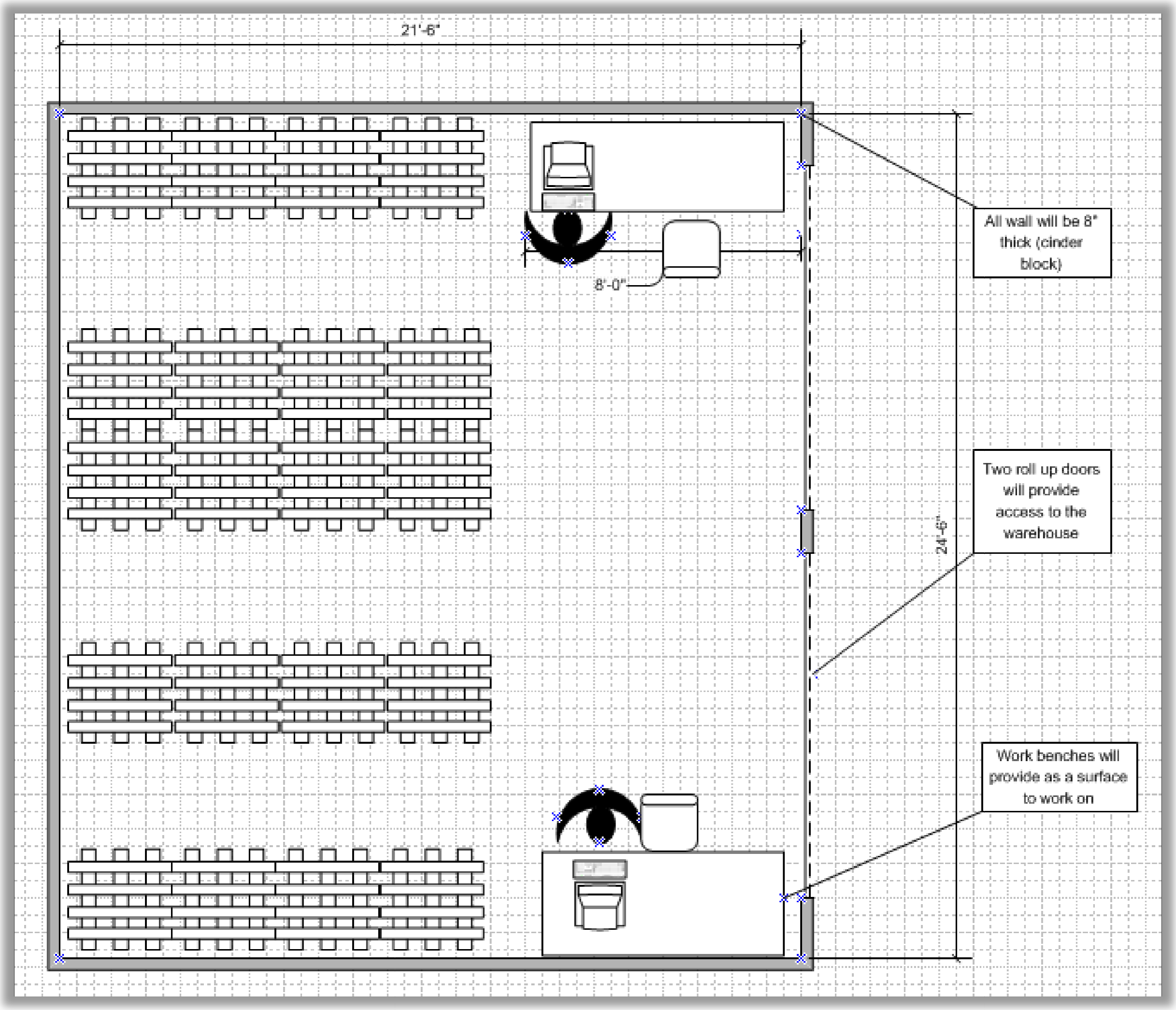


Figure 9 - KIVA System Layout Proposal



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