The Guggenheim Museum is interested in curating a new exhibit. To accomplish this, they have tasked a new art director named Celeste and a local up-and-coming artist named Valentina to put the project together. Valentina began by combing the modern art community for potential artists and pieces. She presented the following list of artists, their pieces, and the price of displaying each piece to several museums. Note, the display price includes the cost of paying the artist for loaning the piece to the museum, transporting the piece to Seattle, constructing the display for the piece, insuring the piece while it is on display, and transporting the piece back to its origin (data is provided in a table below and in an Excel file).

Valentina possesses certain requirements for the exhibit. She would like visitors to become aware of the collage as an art form, but she believes collages require little talent. She therefore decides to include only one collage. Additionally, Valentina wants viewers to compare the delicate lines in a three-dimensional wire mesh sculpture to the delicate lines in a two-dimensional computer-generated drawing. She therefore wants at least one wire mesh sculpture displayed if a computer-generated drawing is displayed. Alternatively, she wants at least one computer-generated drawing displayed if a wire mesh sculpture is displayed. Furthermore, Valentina wants to expose viewers to all painting styles, but she wants to limit the number of paintings displayed to achieve a balance in the exhibit between paintings and other art forms. She therefore decides to include at least one photo-realistic painting, at least one cubist painting, at least one expressionist painting, at least one watercolor painting, and at least one oil painting. At the same time, she wants the number of paintings to be no greater than twice the number of other art forms.

Valentina wants all her own paintings included in the exhibit. In addition, she possesses personal biases for and against some artists. Valentina is currently dating Hector, and he wants both of his paintings displayed. Valentina counts both Darcy and Emma her best friends, and he does not want to play favorites among these two artists. She therefore decides to display as many pieces from Darcy as from Emma and to display at least one piece from each of them. Although Rick is very popular within art circles, Valentina believes Rick makes a mockery of art. Valentina will therefore only accept one display piece from Rick, if any at all.

Celeste also possesses her own agenda for the exhibit. As a museum director, she is interested in representing a diverse population of artists, appealing to a wide audience, and supporting a range of current issues in the exhibit. To support female artists, she decides to include at least one piece from a female artist for every two pieces included from a male artist. To advance environmentalism, she decides to include either one or both of the pieces "Aging Earth" and "Wasted Resources." To advance Native American rights, she decides to include at least one piece by Stuart. To advance science, she decides to include at least one of the following pieces: "Beyond," "Who Has Control," "Where are we now?" and "Pioneers."

Celeste also understands that space is limited at the museum. For this exhibit, the museum only has enough floor space for four sculptures and enough wall space for around 20 paintings, collages, and drawings. Finally, Celeste decides that if "Narcissism" is displayed, "Reflection" should also be displayed since "Reflection" also suggests narcissism.

The museum board of directors must approve each exhibit. Please analyze proposals 1 – 3 below and prepare a memo outlining each of the proposals below for the museum board of directors.

1. **Proposal 1:** The Guggenheim decides to allocate $4 million to fund the exhibit. Given the pieces available and the specific requirements from Valentina and Celeste, formulate and solve a BIP model to maximize the number of pieces displayed in the exhibit without exceeding the budget. How many pieces are displayed? Which pieces are displayed?

2. **Proposal 2:** To ensure that the exhibit draws the attention of the public, Celeste decides that it must include at least 20 pieces. Formulate and solve a BIP model to minimize the cost of the exhibit while displaying at least 20 pieces and meeting the requirements set by Valentina and Celeste. How much does the exhibit cost? Which pieces should be displayed?

3. **Proposal 3:** Apparently Valentina and Celeste were using an old pricing sheet when they made their exhibit decisions. They still want to maintain the same criteria, but realize the cost of each piece of art could increase or decrease by *as much as* 20% of the cost on the old price sheet. That is, the random price change of each piece can range between –20% and +20% independently with equal probability. How does that possibility impact the cost of Celeste's plan in part 2?

The exhibit begins as planned and it is a great success. In fact, many patrons are inquiring how they can purchase some of the art. As a result, Celeste and Valentina decide to create prints of the paintings and photographs in the exhibit for people to purchase. Valentina was able to find a company that could make high quality prints and the museum soon puts her in charge of managing the process.

Several months into the process Valentina finds herself overwhelmed with the print making because they are selling so rapidly. Valentina seeks out help by hiring a former production manager for a print shop named Seymore. However, not long after the hire, Valentina visits the print shop and finds herself disappointed. Valentina sees Seymore and approaches him. "Seymore, I just got back from walking through the shop, and I am upset."
"What's the problem, Mrs. Valentina?"
"Well, you know how much I have been emphasizing the need to cut down on our in-process inventory to increase the number of prints."
"Yes, we've been working hard on that," responds Seymore.
"Well, not hard enough! Do you know what I found by the presses?"
"No."
"Five poster sheets waiting to be printed. And then, right next door at the inspection station, 13 prints! The inspector was inspecting one of them, but the other 12 were just sitting there." (The prints are each inspected by hand to make sure they meet Valentina's quality standards). "We can't have that."

Seymore tries to respond. "Yes, Valentina, I am well aware that that inspection station is a bottleneck. It usually isn't nearly as bad as you found it this morning, but it is a bottleneck. Much less so for the printing press. You really caught us on a bad morning."
"I sure hope so," retorts Valentina, "but you need to prevent anything nearly this bad happening even occasionally. What do you propose to do about it?"
Seymore now brightens noticeably in his response. "Well actually, I've already been working on this problem. I have a couple proposals on the table and I have asked my analyst to review these proposals and report back with recommendations."
"Great," responds Valentina, "glad to see you are addressing the problem. Give this your highest priority and report back to me as soon as possible."
"Will do," promises Seymore.

Here is the problem that Seymore and his analyst are addressing. Each of 10 identical presses is being used to print reproductions of the paintings and photographs. The poster sheets arrive randomly to the group of presses at a mean rate of 7 per hour. The time required to make a print has an exponential distribution with a mean of 1 hour. When finished, the prints arrive randomly at an inspection station at the same mean rate as the sheets arrived at the presses (7 per hour). A single inspector has the full-time job of inspecting the prints to make sure they meet Valentina's quality specifications. Each inspection takes him 7.5 minutes, so he can inspect 8 prints per hour. The arrival and inspection rates have resulted in a substantial amount of in-process inventory at the inspection station (i.e., the average number of poster sheets waiting to complete inspection is fairly large), in addition to that already found at the machines.

The cost of this in-process inventory is estimated to be $8 per hour for each poster sheet at the presses or

each print at the inspection station. Therefore, Seymore has made two alternative proposals to reduce the average level of in-process inventory.

Proposal 4: Take slightly longer to make the prints (which would increase their average time to make a print to 1.2 hours), so that the inspector can keep up with his output better. This also would reduce the cost of the power for running each press from $7.00 to $6.50 per hour. (By contrast, decreasing the time would increase this cost to $7.50 per hour while decreasing the average time to make a print to 0.8 hour.)

Proposal 5: Substitute a more experienced inspector for this task. She is somewhat faster at 7 minutes per poster, so she should keep up better. However, this inspector is in a job classification that calls for a total compensation (including benefits) of $19 per hour, whereas the current inspector is in a lower job classification where the compensation is $17 per hour.

You are the analyst on Seymore's staff who has been asked to analyze this problem. He wants you to see how much each proposal would cut down on in-process inventory and then make your recommendations.

4. To provide a basis of comparison for Seymore, begin by evaluating the status quo. Determine the expected amount of in-process steady state inventory at the presses and at the inspection station. Then calculate the expected total cost per hour when considering all of the following: the cost of the in-process inventory, the cost of running the presses, and the cost of the inspector.

5. What would be the effect of proposal 4? Why? Make specific comparisons to the results from part 4 above. Explain this outcome to Seymore, who does NOT understand technical terms from queueing theory.

6. Determine the effect of proposal 5. Make specific comparisons to the results from part 4 above. Explain this outcome to Seymore, who still does NOT understand technical terms.

7. Make your recommendations for reducing the average level of in-process inventory at the inspection station and at the group of machines. Be specific in your recommendations, and support them with quantitative analysis like that done in part 4. Make specific comparisons to the results from parts 5 and 6, and cite the improvements that your recommendations would yield

Please submit two separate memos, one for parts 1 – 3 to the museum board of directors and one for parts 4 – 7 for Seymore, each should be an html file generated from an R Notebook. I recommend completing your analysis and memo for each part (1 – 3 and 4 – 7) in separate R Notebooks. Submit the two html memos and the two R Notebooks to Canvas.

Artist	Piece	Description of Piece	Price
Nicholas	“Perfection”	A wire mesh sculpture of the human body	$300,000
	“Burden”	A wire mesh sculpture of a mule	$250,000
	“Emergence”	A wire mesh sculpture of a man	$125,000
Rita	“Beyond”	A series of computer-generated drawings	$400,000
	“Who Has Control?”	A computer-generated drawing intermeshed with lines of computer code	$500,000
	“Domestication”	A pen-and-ink drawing of a house	$400,000
	“Innocence”	A pen-and-ink drawing of a child	$550,000
Norm	“Aging Earth”	A sculpture of trash covering a larger globe	$700,000
	“Wasted Resources”	A collage of various packaging materials	$575,000
Hector	“Serenity”	A painting with an all blue watercolor background and a black watercolor center	$125,000
	“Calm Before the Storm”	An all blue watercolor painting	$300,000
Robert	“Void”	An all black oil painting	$150,000
	“Sun”	An all yellow oil painting	$150,000
Emma	“Storefront Window”	A photo-realistic painting of a jewelry store display window	$850,000
	“Harley”	A photo-realistic painting of a Harley-Davidson motorcycle	$750,000
Angie	“Consumerism”	A collage of magazine advertisements	$400,000
	“Reflection”	A mirror (considered a sculpture)	$175,000
	“Trojan Victory”	A wooden sculpture of a horse	$450,000
Darcy	“Ziggy”	A photo-realistic self-portrait (painting)	$500,000
	“Ziggy II”	A cubist self-portrait (painting)	$500,000
	“Ziggy III”	An expressionist self-portrait (painting)	$500,000
Bill	“Where are we now?”	A science fiction oil painting depicting Mars colonization	$650,000
	“Pioneers”	An oil painting of three astronauts aboard the space shuttle	$650,000

Stuart	“Wisdom”	A pen-and-ink drawing of an Apache chieftain	$250,000
	“Superior Powers”	A pen-and-ink drawing of a traditional Native American rain dance	$350,000
	“Living Land”	An oil painting of the Grand Canyon	$450,000
Candy	“Study of a Violin”	A cubist painting of a violin	$400,000
	“Study of a Fruit Bowl”	A cubist painting of a bowl of fruit	$400,000
Rick	“My Namesake”	A collage of Rick cartoons	$300,000
	“Narcissism”	A collage of photographs of Rick	$300,000
Valentina	“All That Glitters”	A watercolor painting of the Golden Gate Bridge	$50,000
	“The Rock”	A watercolor painting of Alcatraz	$50,000
	“Winding Road”	A watercolor painting of Lombard Street	$50,000
	“1071 Fifth Ave”	A watercolor painting of The Guggenheim	$50,000