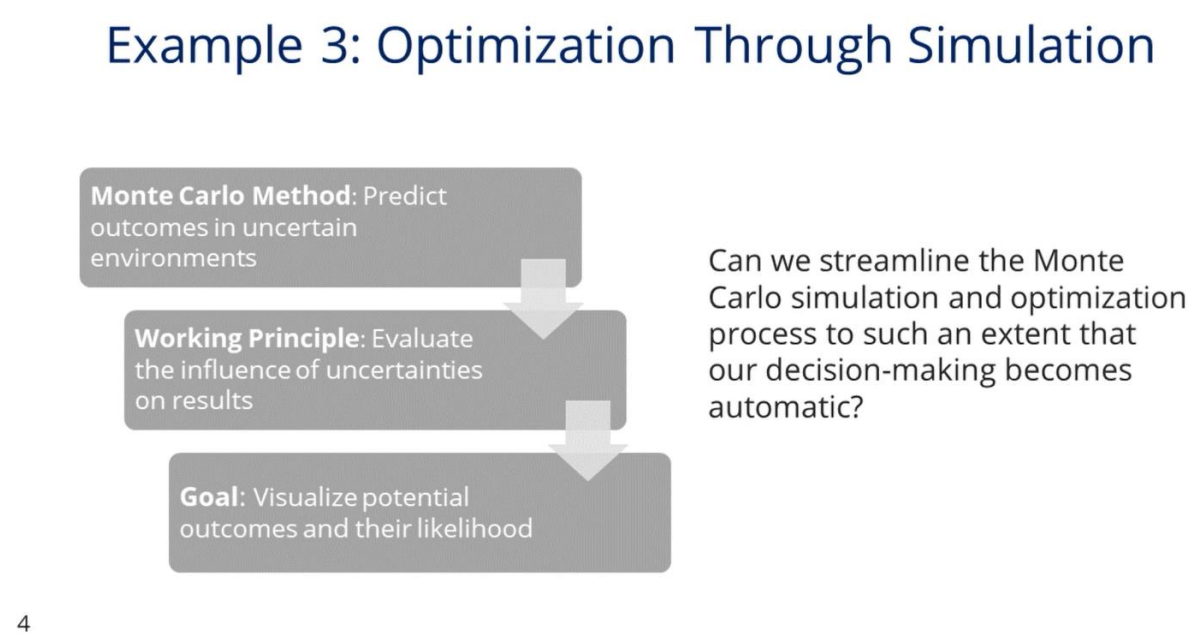
M8L5. Optimization with Uncertain Variables

Slide #1

Slide #2



In our discussions of the Monte Carlo method, we have uncovered its power to predict the outcomes of various decision options under uncertain business environments.

At its core, this method evaluates how uncontrollable elements of business uncertainty influence the results of choices we can control.

By doing so, it allows analysts to visualize a range of potential outcomes. along with their likelihoods presented as confidence intervals.

This opens an interesting possibility.

Can we streamline the Monte Carlo simulation and optimization process to such an extent that our decision making becomes automatic?

In the following section, we will explore how to create a data-driven decision-making system wherein the optimal capital investment decision is determined by the computer necessitating minimal human intervention.

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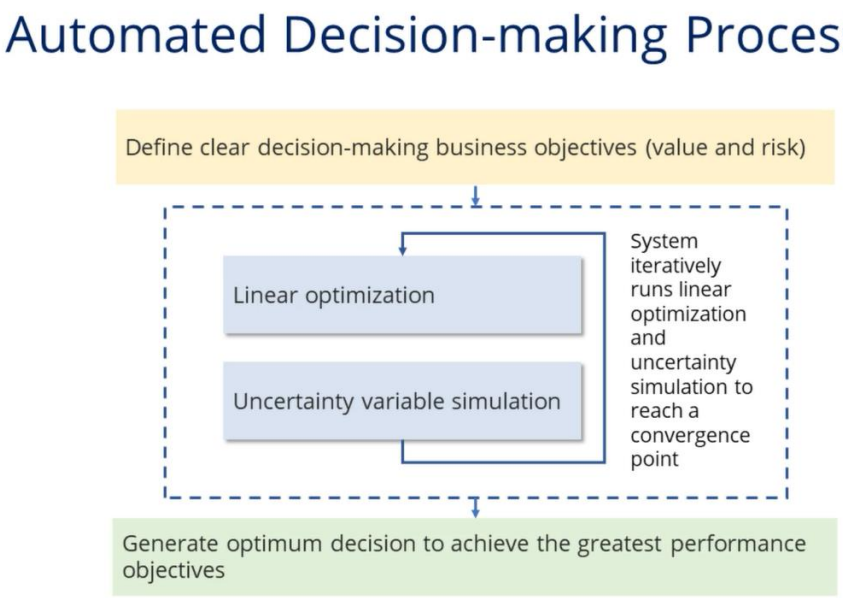

To achieve this objective, we must address three business and technical challenges.

First, clearly defining the business objectives is crucial.

These should articulate the business's key value drivers and delineate risk tolerance boundaries, ensuring alignment with its strategic goals.

Solver presents a powerful digital solution for integrating a simulation model with an optimization model.

The system iteratively runs linear optimization and uncertainty simulation to reach a convergence point considering specific objectives and boundary conditions predetermined by decision makers.

This streamlined process can generate an optimized decision with the simple click of a button.

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Optimization Through Simulation Case Study

Capital Investment Scenario Analysis Case

Description: As the chief operation officer a manufacturing company, you need to decide on the capital investment on additional machines and associated labor for the next year to meet growing market demand.

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As the Chief Operating Officer of a manufacturing company preparing for increased market demand next year, you are tasked with making key capital investment decisions regarding the acquisition of additional machines and the hiring of more labor.

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Business Economic Model

Uncertain Business variables

Uncertain variables (forecast)	Likely case	Recession	Strong economy
Sales demand growth	6%	2%	8%
Unit price growth	2%	1%	4%
Material price growth	2%	1%	4%
Fixed cost price growth	2%	1%	4%

Decision options

Range of additional machines
1
6

Forecast of uncertain variables	Simulation Case	Recession	Strong economy	Likely case
Sales demand growth	6%	2%	8%	6%
Unit price growth	3%	1%	4%	2%
Material price growth	3%	1%	4%	2%
Fixed cost price growth	2%	1%	4%	2%

Simulation case

Demand, delivery and revenue	Current year	Next year (additional machine)	Next year (status quo)
Annual sales demand	700,000	738,696	738,696
Annual delivery	700,000	710,000	700,000
Unit price	$ 250.00	$ 258	$ 258
Annual revenue	**175,000,000**	**183,436,907**	**180,853,289**
Production capacity			
# of machines	70	71	70
Capacity per machine	10,000	10,000	10,000
Total capacity	700,000	710,000	700,000
Total production	700,000	710,000	700,000
Variable cost			
Variable cost per unit	$ 150.00	$ 155	$ 155
Total variable cost	**$ 105,000,000.00**	**$ 110,038,372**	**$ 108,488,536**
Fixed cost			
Machine and operating labor (per machine)	$ 720,000.00	$ 731,858	$ 731,858
Total machine and operating labor cost	$ 50,400,000.00	$ 51,961,891	$ 51,230,034
Others	$ 4,000,000.00	$ 4,065,876	$ 4,132,836
Total fixed cost	**$ 54,400,000.00**	**$ 56,027,767**	**$ 55,362,870**
Total cost	159,400,000.00	$ 166,066,139	$ 163,851,406
Total profit	**15,600,000.00**	**17,370,768**	**17,001,882**

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Your decision-making toolkit includes a model that incorporates four variables reflecting market uncertainties alongside a crucial decision parameter, the number of additional machines to invest in.

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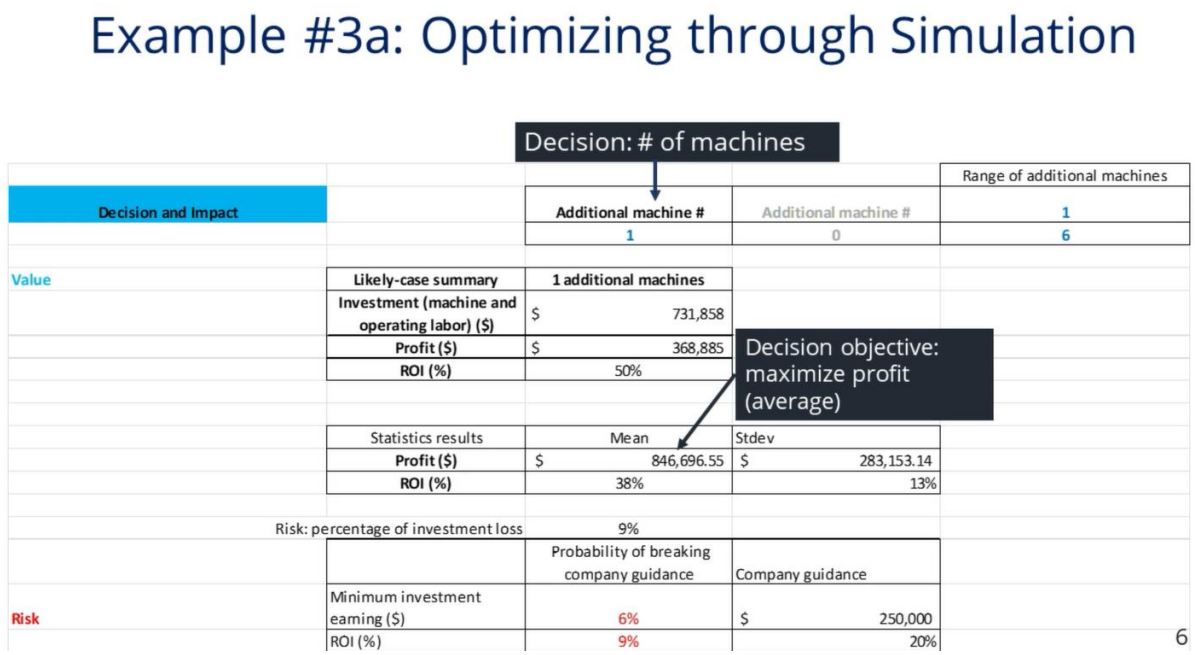

The critical decision at hand is to determine the optimal number of machines to invest in, with choices ranging from one to six machines.

For our first scenario, the guiding criterion for decision making is profit maximization.

The goal is to use the model to identify the investment in machines that maximizes profit compared to a scenario with no additional investment.

In addition, the automated decision-making system incorporates the company's financial guidelines.

For instance, the minimum profit expected from capital investment is $250,000 and its return on investment should exceed 20%.

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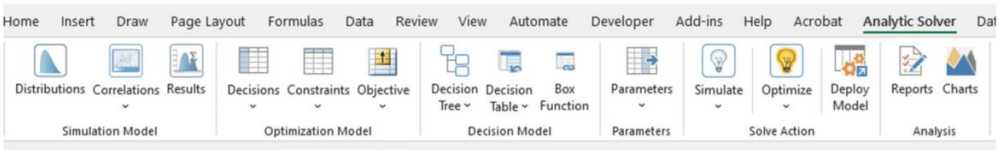
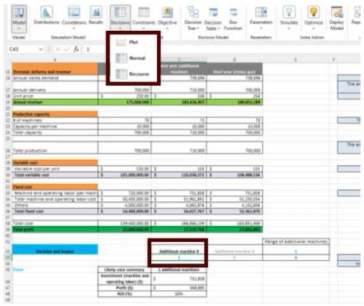
Analytic Solver Simulation Model





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Constructing a streamlined system for decision optimization through uncertainty simulation involves two primary phases.

Simulation model. Begin by specifying uncertain variables, outcomes, and their statistical results in the simulation model. This process is designed to autonomously generate decisions utilizing an optimization algorithm, thereby eliminating the need for specifying a simulation parameter to represent decision options.

Optimization model. Use the optimization menu of Solver to configure the optimization model, including decision variables, constraints, and objectives consistent with prior discussion. The goal is to maximize average profit as determined by the statistical outcomes of simulation model iterations. Constraints are applied to ensure the number of machines is within an acceptable range, one to six and recognized as an integer.

This workflow creates an automatic process for optimizing decisions, facilitating the maximization of average profit within established constraints.

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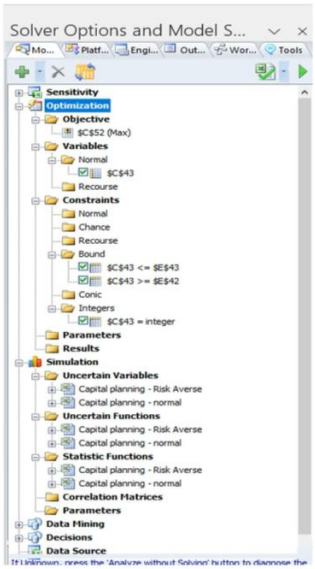
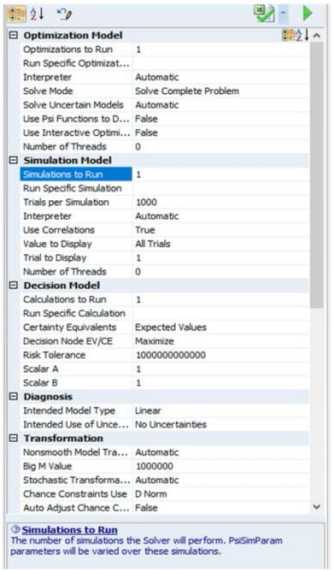
Streamline Optimization and Simulation Model





The solver model window provides a comprehensive summary of the optimization and simulation configurations.

The optimization model includes a decision variable, which is the number of machines to invest in, constraints that delineate the permissible range of machines, and an objective aimed at maximizing average profit.

The simulation model incorporates uncertain variables, namely the four business factors, uncertain functions related to profit and return on investment and statistical functions that calculate the mean and standard deviation values of profit and return on investment respectively.

It is important to note that the simulation model omits a parameter her variable. because the optimization algorithm is tasked with generating the decision option autonomously.

The solver platform window outlines the details of the simulation and optimization execution.

1000 trials will be conducted in each simulation run to assess the impact of market uncertainty on business performance.

Additionally, the number of simulation runs will be set to the default value of one as Solver is designed to automatically determine the number of simulation runs based on the iterations needed to achieve optimization convergence.

After finalizing the streamlined model configuration, clicking the Run button initiates the decision-making process.

The system then proceeds through iterations to achieve optimal convergence.

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Optimization Simulation: Result

				Range of additional machines
Decision and Impact		**Additional machine #**	Additional machine #	1
		3	0	6
Value	**Likely-case summary**	**3 additional machines**		
	Investment (machine and operating labor) ($)	$ 2,218,177		
	Profit ($)	$ 929,209		
	ROI (%)	42%		
	Statistics results	Mean	Stdev	
	Profit ($)	$ 851,803.56	$ 279,029.95	
	ROI (%)	39%	13%	
		Probability of breaking company guidance	Company guidance	
Risk	Minimum investment earning ($)	6%	$ 250,000	
	ROI (%)	9%	20%	

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In our example, the model recommends investing in three machines as the optimal strategy to maximize profit from the investment.

This decision leads to the highest average profit of $851,000 accompanied by a return on investment of 39%.

The decision to invest in three additional machines generated automatically by the model aligns with the choices we made previously, which were informed by a model assisted decision-making process.

Regarding risk, there is a 6% chance that the investment will yield a profit lower than the company's minimum expected profit of $250,000 from capital investment.

Similarly, there is a 9% probability that the return on investment will fall below the company's minimum expectation of 20%.

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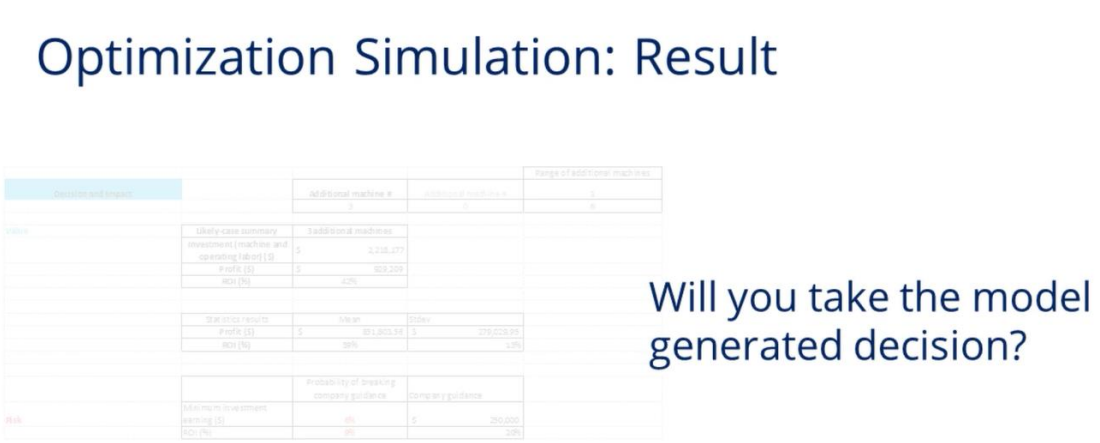

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Would you proceed with the model generated decision?

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Optimization Simulation Example 3b: Balance Value and Risk

	Probability of breaking company guidance	Company guidance	Risk tolerance level
Minimum investment earning ($)	6%	$250,000	5%
ROI (%)	9%	20%	5%

Optimization

- Variables
- Constraints
- Objectives
- Risk tolerance

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The example currently treats financial investment risk factors as optional criteria, not incorporating them directly into the automated decision-making process.

However, the model can be enhanced by integrating both value objective and risk tolerance measures.

In an improved model, the minimum return and the return on investment threshold values are programmed as constraints within the optimization model.

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Optimization Simulation Example 2b: Result

				Range of additional machines
Decision and Impact		**Additional machine #**	Additional machine #	1
		2	0	6
Value	**Likely-case summary**	**2 additional machines**		
	Investment (machine and operating labor)	$ 1,475,098		
	Profit change	$ 716,624		
	ROI	49%		
	Statistics results	Mean	Stdev	
	Profit change	$ 663,798.93	$ 52,366.80	
	ROI	45%	3%	
		Probability of breaking company guidance	Company guidance	Risk tolerance level
Risk	Minimum investment earning ($)	0.1%	$ 250,000	5%
	ROI (%)	0.2%	20%	5%

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Run the improved model.

The system recommends investing in two machines as the optimal strategy to maximize the investment's profit.

This decision results in an average profit of $653,000, accompanied by a return on investment of 45%.

Opting to invest in two additional machines yields a lower expected return than investing in three machines, but embraces a more conservative approach to risk management.

There is a less than 1 percent chance that the investment will yield a profit lower than the company's minimum expected profit of $250,000 from capital investment.

Similarly, the probability that the return on investment will fall below the company's minimum expectation of 20% is also less than 1%.

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Optimization Simulation Example 2b: Result

Decision and Impact		Additional machine #	Additional machine #	Range of additional machines
		2	0	1 / 6
Value	Likely case summary	2 additional machines		
	Investment (machine and operating labor)	$ 1,475,088		
	Profit change	$ 716,624		
	ROI	49%		
	Statistics results	Mean	Stdev	
	Profit change	$ 663,798.93	$ 52,366.80	
	ROI	45%	3%	
		Probability of breaking company guidance	Company guidance	Risk tolerance level
Risk	Minimum investment earning ($)	0.1%	$ 250,000	5%
	ROI (%)	0.2%	20%	5%

What do you think about the risk-averse decision?

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Would you proceed with this model generated risk-averse decision?

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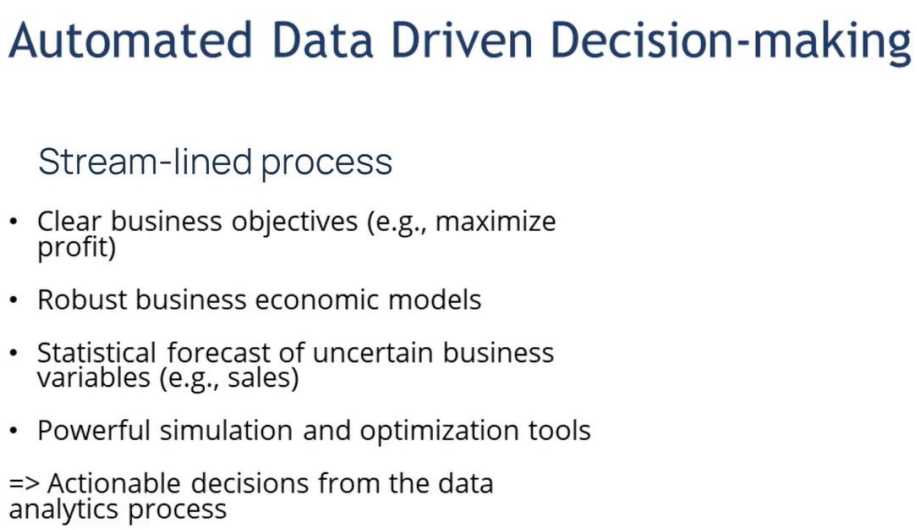

The streamline process involves four crucial components.

One, clear business objectives.

The quantitative performance measures shall be closely aligned with the company's strategy.

Two, robust business economic models are capable of accurately estimating the financial performance of a business.

Three, statistical forecasts of uncertain business variables.

Four, advanced simulation and optimization tools.

The tools can manage complex business models and convergence calculations efficiently.

Furthermore, the system shall be designed to generate actionable decisions from the data analytics process, moving beyond mere suggestions of feasible paths.

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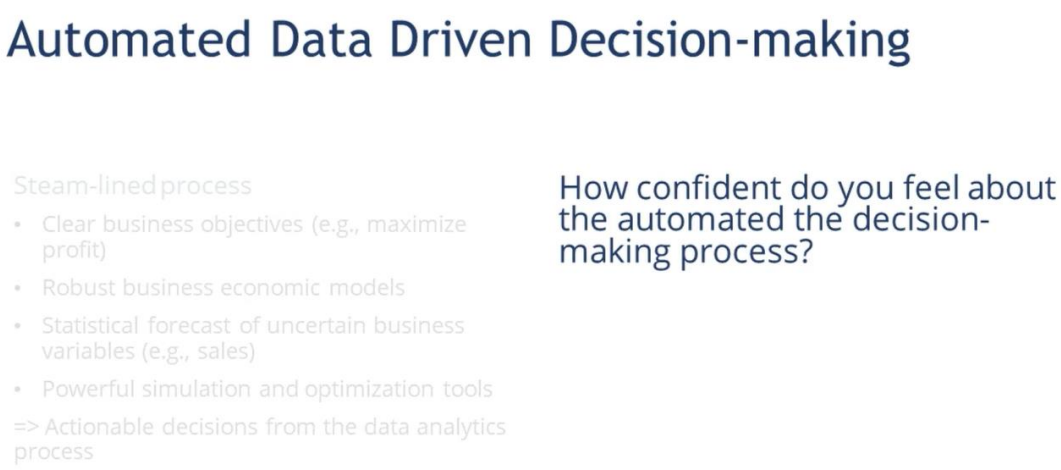

Reflecting on real-world case studies, demonstrated uses, and our interpretation of data analytics results, how confident do you feel about the automated decision-making process?

Additionally, what roles can human experts play to enhance the reliability and efficiency of this process?

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