Incorporate Data Analytics Tools to Optimize the SLP Method with Application to a Plant of a Leading Global Company

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Abstract

The correct design layout of a plant is fundamental for a manufacturing company to function efficiently. Finding out how to arrange the equipment of a plant is essential to manufacture agriculture and construction equipment. This project aims to refer to the Systematic Layout Planning (SLP) method followed to design the best scenario of resources required for a plant of a leading global company. The information gathered during the SLP, is used to generate a mathematical programming model incorporating data analytics tools to speed up the work done and results found with SLP. Following that, a model with a genetic algorithm is developed to find good results that are necessary for the decision making for a plant redesign.

Keywords
Systematic Layout Planning, Data Analytics, Genetic Algorithm, and Neural Networks

1. Introduction

A leading global manufacturer company located in South America forecasted an increase in the demand of agriculture machinery within the next five years and the actual capacity of the plant is of 94%. In order to increase the efficiency of the distribution of the plant, and increase the production capacity, in 2018 the company decided to implement the Systematic Layout Planning. According to Maina, Muchiri and Keraita (2018), the Systematic Layout Planning (SLP), aims to systematically organize and establish all production stations within a facility with the purpose of improving the production operations of a company. This process took 1 full year and 25 human resources. They did calculations in an outdated software to find the inputs for the SLP and worked manually to generate the different alternatives for the layout redesign. However, despite the effort and resources used, the results were limited by the experience and creativity of the people involved. This situation led to the inaccuracy of 10,000 square meters, that was not contemplated before in the layout planning redesign.

Ficko and Palcic (2013) highlight the importance of using intelligent algorithms to optimize the design of the facilities. Intelligent algorithms help to find the best solution within a search space consisting of all possible and feasible solutions. This paper proposes the application of a mathematical programming model to determine the inputs required to develop the SLP in the agriculture machinery manufacturer located in South America. This model helps reduce the time and resources used to implement the SLP, determines the best scenario of required resources in order to meet the upcoming increasing demand and has the quality to be replicable in any other company of the same industrial branch.

In this paper, section two shows the literature review made before developing the proposal. Different methodologies related to layout problems throughout the years, genetic algorithms and neural networks were reviewed. Then, it is described the solution method proposed for the company. It was studied in detailed the software used, the difference between what the company does nowadays and what is intended to do with the new application. Section four, shows the results of the software, and finally, the conclusions are shown in section four.

2. Literature Review

2.1 Layout problems and methodologies

With the rapid increase of demand in the agricultural machinery industry, factories need to increase their production capacities and efficiency to compete against their market rivals. They need to develop lean processes in order to have the lowest cost with the highest effectiveness (Wiyaratn and Watanapa 2010). Throughout the years, the design plant problems have been present. This problem consists in finding the best design layout taking into account the connections between areas that has to exist to layout the production, in order to make the plant more efficient and with more safety (Caputo et. al., 2015). Since the twentieth century, methods had been improved to solve these problems; in 1950 the Immer method showed up, which only sees the materials flow in an existent plant and solve minimal adjustments on it. Zheng (2015) introduced a method related to the game theory to foster the multidisciplinary decision-making process involved in the layout problem and developed a strategy to define the amount of equipment required for the problem in study, in order to work with the highest possible level of performance. Then the Reed methodology appears, which is focused on the material flow of activities. In 1961, R. Joseph proposed a method that helped plant's designers to develop quantitative analyses based on data from previous qualitative analyses. Jinghua, Hui, Shichao, Xiaoyuan, and Liuling (2018) mentioned that this method works in the industrial field, and also with different types of design optimization; it is still used, improved, and innovated nowadays. In 1976 the SLP method was created by Muther, which is one of the most popular method and is used actually by many industries (Paredes et. al., 2016).

The primary aspiration of any plant is to make the manufacturing process smoother, and they can reach that through layout planning, with the purpose of achieving what is already mentioned above. Seeing this from another perspective, for the layout planner the final product or the output is the installed layout, hence, the design of this layout is the combination of number of components and products of the specific industry (Muther and Hales, 2015).

The Systematic Layout Planning (SLP) is a method used to generate different layout design proposals to improve the material flow and productivity (Barnwall y Dharmadhikari, 2016). The SLP method is divided into four phases: localization, general distribution, detail distribution, and installation. It takes as inputs products, quantity, routes, spaces, time levels, and activities. As shown in Figure 1, the inputs are used to evaluate the material flow and the activity relationship between work centers and raw material, in order to create a relationship diagram. For the next phase, the space needed, and the availability must be known to develop a relationship map of space. When phase 2 is done, the practical limitations and changes must be considered to formulate different proposals of the design layout. Once the proposals are done, they must be evaluated to select and implement the best one. The SLP method is the method we are going to incorporate data analytics tools to, by using the CRISP-DM method.

Additionally, to the SLP methodology there are another mathematical optimization models Komaki et. al. (2014) and Amar and Abouabdellah (2016), elaborated a head-tail method to design functional areas. They enriched the partially constructed layout using a pair-wise method with the closeness of flow and distance. Asl and Wong (2015) examined the unequal area facility layout problem with the aspiration of minimizing the total material handling costs. Sun and Gao (2017) design the models for minimizing the total time considering the travel time of road sections and intersections. Zhang et al. (2017) offered multiobjective cooperative and co-evolutionary algorithm to solve a layout optimization problem of satellite modules.

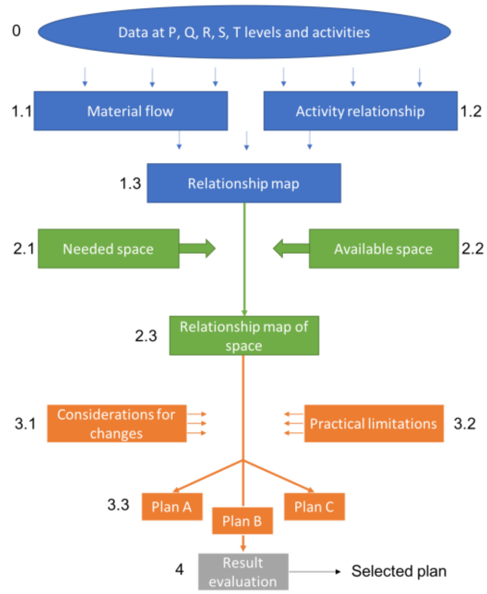


Figure 1. SLP Diagram (Own elaboration)

2.2 Genetic algorithms

Genetic algorithms are heuristic search methods that are based on what is known of the natural evolution process. They were developed by John Holland and students of the University of Michigan in the sixties, with the objective of the development of a model of adaptation, studying the phenomena of adaptation in both natural and artificial systems (Kuri and Galaviz, 2009). The authors Kuri and Galaviz mention that nowadays, genetic algorithms are used as methods to find optimal solutions that help simulate natural evolution. These have been capable of solving problems about "optimization of real functions and machine learning mechanisms". Genetic algorithms have gained popularity because they provide the possibility of addressing problems in which it is very complex to apply traditional mathematical procedures (2009).

In the 70's decade, when technology invented the intelligent algorithms, they started a period of strong development, and now they're widely used to generate successful solutions for the facility layout design (Jinghua et al, 2018). Authors as Jinghua et. al, Z.J. Gang et al, F. Ozcelik and Islier, and Ky Tam, had used genetic algorithms in layout problems and have proved their strength in different examples.

Also, genetic algorithms are constantly used to solve facility layout problems. The authors Hernández Gress et. al. (2011), recommended a genetic algorithm using possible binary variables assignment for the block layout design problem for unequal areas. Hasda et. al. (2016), suggested a new interactive evolutionary genetic algorithm on local search algorithm for solving static static facility layout problems with unequal cubicles.

2.3 Neural networks

As mentioned before, the algorithms have been used over time to solve problems with the use of a computer, and it has worked successfully. However, there are currently problems with greater complexity in which it is not enough to solve them with the aforesaid algorithms. Therefore, neural networks arise as an alternative to solve problems with greater difficulty, and they are qualified to solve them since they are capable of learning. So, a neural network is an "information process system" where it receives inputs to process them and thus generates outputs, this is formed by neurons that are the processing units that are interconnected by connections. Each neuron has a transfer function and each connection acquires a weight.

The important thing with neural networks is knowing how to define the weight of the connections to carry out the expected task. This is the task performed by learning algorithms, who through examples modify the arrangement of neurons, as well as their connections and therefore their weights, so that neural networks learn from these examples (Gómez, 2015).

3. Application or solution method

As mentioned before, the plant located in South America forecasted an increase of 54% in the demand for agriculture machinery within the next five years and the actual capacity of the plant has reached 94%. Since 2014, the company does 10 SLP per year in its plants around the world. In order to increase the efficiency of the distribution of the plant and the production capacity, for 1 year, 25 employees of different parts of the world implemented SLP. Since this method is developed manually, according to Barnwall and Dharmadhikari, the method is limited by the experience and creativity of the employees, the results have mistakes and biases. The information gathered to obtain different proposals was arranged in an outdated software, but the data was disorganized, not automatized, not replicable to use for any plant of the company; the data was subject to people manipulation, it took total time of six months to arrange the data, it was expensive, and it needed a high number of human resources to elaborate it. At the end of the year, the employees developed 7 proposals of the layout redesign; they evaluated the advantages and disadvantages of each one of them, and finally, they selected the best proposal for the implementation. Even though they selected the best proposal, they had an inaccuracy of 10,000 m² that were not contemplated before in the layout planning redesign. In order to improve the SLP method development, our proposal is to incorporate data analytics tools to SLP, by using the CRISP-DM method.

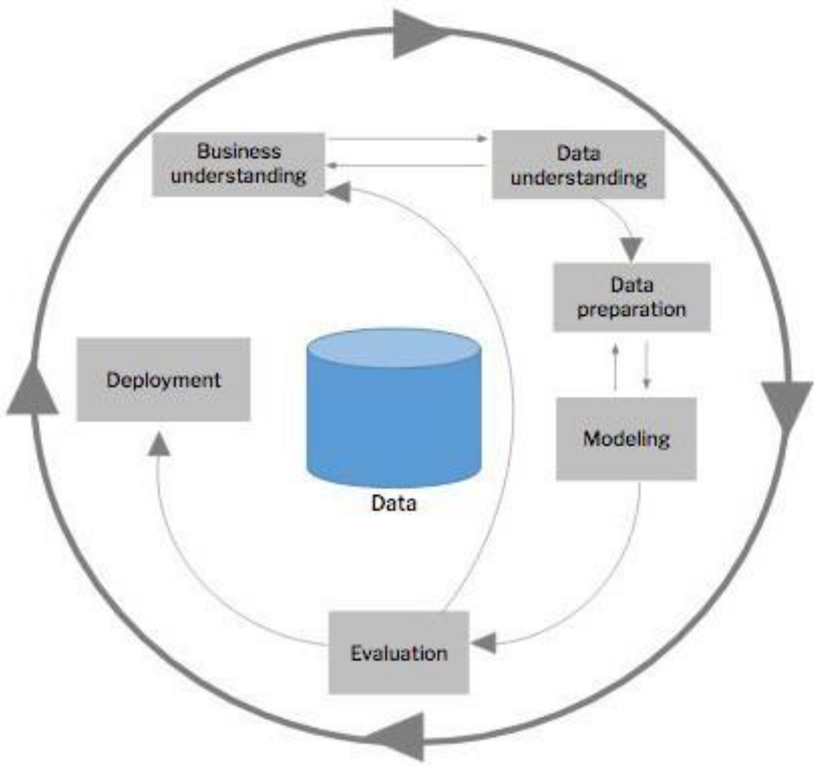
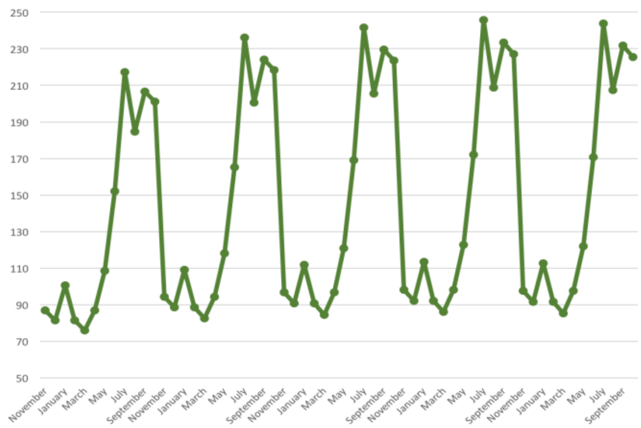


Figure 2. CRISP-DM method.

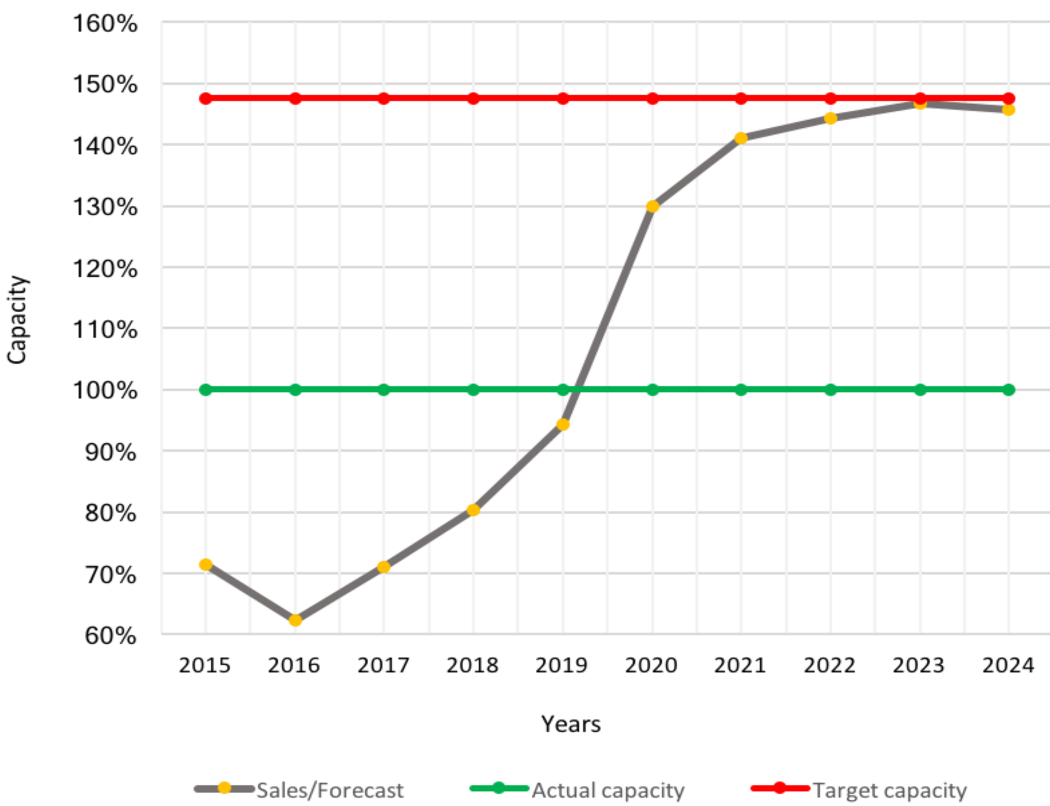
CRoss-Industry Standard Process for Data Mining (CRISP-DM) is a method for data mining. The life cycle of a data mining project consists of six phases (Figure 2). However, the sequence of the phases are not rigid, since it is required to return between them. The outcome of each phase determines which phase, or task of a phase, must follow. As shown in Figure 2, the arrows indicate the most important dependencies between the phases. Data mining does not end once a solution is implemented. For the incorporation of data analytics tools to optimize the SLP method the deployment phase is beyond the scope of our proposal.

Figure 2. CRISP-DM method.



Graph 1. Cyclicity of the product.

Phase 1 is the business understanding, which consists in understanding the objectives and requirements of the project from the client's perspective to define a data mining problem and a preliminary plan for achieving the objectives. Regarding this project, it is understood that is for a plant located in South America and the product under study is a sprayer, which has an increase cyclicity during the forecasted years (Graph 1). As shown in Graph 2, the plant forecasted an increase of 54% in the demand for agriculture machinery within the next five years and the actual capacity of the plant has reached 94%.



Graph 2. Product capacity, sales, and demand.

It was studied the measurements of the plant areas, for example, the primary area measures 2,005 m², welding 3,800 m², paint 6,500 m², and assembly 5,970 m². The material process starts in the first area, where a metal slab is received to cut it and give it form; then the pieces go to the second area subassemblies are made and cool the product; next, goes to the third area where it is washed, dried, painted, cured, and workers check its quality; finally, the product goes to the fourth area where all its final pieces are put together.

Table 1. Area, resources, process time, and amount of material received of each area.

	Fist area	Second area	Third area	Fourth area
Area (m²)	2,005 m²	3,800 m²	6,500 m²	5,970 m²
Resources	30	45	7	50
Process Time (min)	90	135	30	100
Amount of Material Received	191	438	722	15,071

The actual capacity of the plant is of producing 10 products per day. It is forecasted that for the next 5 years the plant will need to have the capacity of producing 15 products per day.

Phase 2 is the data comprehension, which begins with data collection and continues with activities that allow you to be familiar with the data, identifies data quality problems, discover the first impressions of the information, and detect subsets to formulate a hypothesis of the information that is hidden. Regarding this project, based on the literature review made, the critical variables were defined. The critical variables are the market share of the company, market behavior, aggregate sales forecast by model, historical demand, seasonality, material flow, work calendar, take rate by SKU, processes, shift role, internal and external operative cost, depreciation cost, area availability, inventory policies of finished products and catalog of machines with their features and technical-operational specifications. As shown in Figure 3, the inputs help develop a mathematical programming model, with a master schedule planning and a second model with a genetic algorithm.

Phase 3 is the data preparation, which covers the necessary activities to build the final data set. Data preparation activities are likely to be performed multiple times and not in a prescribed order. The tasks to be performed include the selection of tables, records, selecting attributes, transforming and cleaning information for modeling tools.

Phase 4 is modeling, in which various modeling techniques are selected and applied, calibrating the parameters to their most optimal values. Commonly, there are several techniques for the same type of data mining problem and some techniques have specific requirements on the form of the data. In modeling, it is sometimes necessary to return to the data preparation phase.

Phase 5 is evaluation, at this stage, a high-quality model will have been built from the perspective of data analysis. Before implementing the model, it is essential to evaluate and review the steps that were followed to develop it, in order to ensure that the model achieves the established objectives. A key objective is to determine if there is an important business problem that has not been sufficiently considered. Finally, a decision must be taken about the use of data mining results.

Our solution proposal, shown in Figure 3, is divided by 3 phases which include 3 different models. For the first model, the market share of the company, market behavior, aggregate sales forecast by model, historical demand, material flow, work calendar and the take rate by SKU are needed to create a mathematical programming model and a master schedule planning by day, shift, and SKU. The first model pretends to replicate what was done in SLP, but coded in the MATLAB® software. Once the mathematical programming model is done, the process, shift roles, external and internal operative costs, depreciation cost, available area, material flow, inventory policies of finished products, a catalog of machines used with their features and technical-operational specifications are used to create a second model with genetic algorithm model.

The second model pretends to give optimal scenarios with the amount of the number of machines required, OFP strategy, labor requirement, and operational cost requirements; optimal inventory levels, resources to use, utilization, efficiency, cost required and required area (without optimization). The genetic algorithm is used to solve the model. The genetic algorithm designs chromosome coding, crossover, mutations and algorithm using MATLAB®. The company must determine which of the solutions is most feasible to implement. If the solution selected does not need any additional infrastructure, the process ends; if yes, then a mixed-integer linear programming (optimization in two dimensions) model must be done. The third model must take as input the budget, current encoded layout, material flow, and the government and security laws.

The third model pretends to create different scenarios including processes, building expansion, cost per square meter, equipment area required, material flow, area required, RIP required, and quality is required in order to have the square meters required, total investment required, production capacity, personnel requirements, equipment requirements, total cost, and service level. If the optimal solution of the third model is not feasible for the company, then new constraints must be taken into account to improve the genetic algorithm model made.

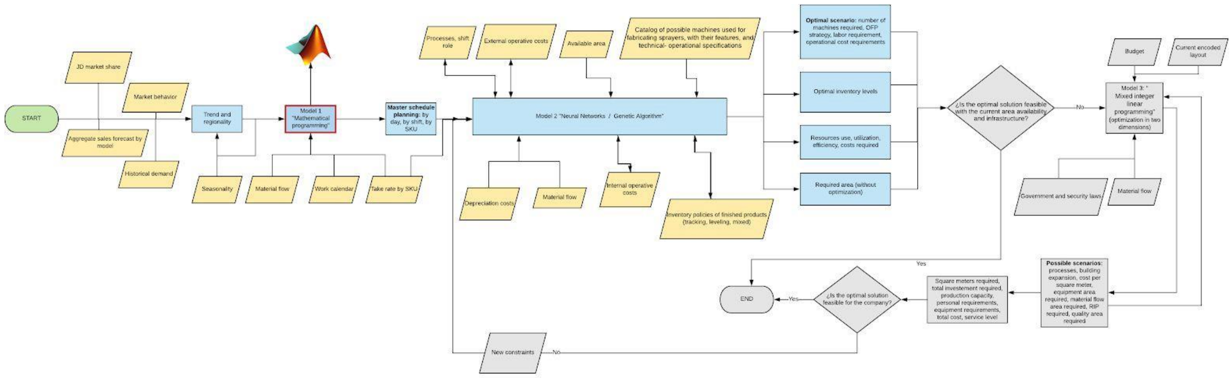


Figure 3. Project Flow Chart

In this paper, only phase 1 of the flow chart in Figure 3 (the mathematical programming) is developed, using MATLAB®. The model can be run multiple times to be capable of obtaining the best solutions.

The aggregated value of what is proposed is that our flow chart (Figure 3) generates better results for future investigations, than the SLP methodology, since every step added on it covers all the requirements of it. Nevertheless, the layout redesign process is now supported with algorithms and mathematical models, plus it is not manually made. Our model intends to leave the code in order to give the client the possibility to be programmed in any other software of their preference. Also, because the critical variables are defined, the model proposed can be replicable in any other factory.

3.1 Results

After running the model that was programmed in MATLAB®, it gives as outputs that for the next five years the annual production must be around 1,700 units and the daily demand capacity of 16 units. The model indicates that the current area is of 27,820 m^2 and it will be needed around 3,500 m^2 more, 550 m^2 for the first area, 600 m^2 for the second area, and 2,300 m^2 for the fourth area. The total amount of manpower needed is of 220 more, 60 for the first area, 60 for the second area, 30 for the third area, and 70 for the fourth area. According to MATLAB®, to complete what was mentioned before, an investment of approximately 13.2 millions of dollars are needed. The data obtained through this software is at an aggregate level.

4. Conclusion

In this paper, the authors have developed a new technique to redesign a layout in order to increase the production capacity of a plant. This method is based in the SLP methodology, but a genetic algorithm is introduced to explore all possible combinations of the critical variables related to the layout problem. The case study illustrates that our proposal is a viable method in solving a layout redesign and improvement problem.

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Biographies

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Stephanie Arreola, a current student of Business Management Engineering at Universidad de Monterrey (UDEM), is in her ninth semester. She has international experience in Heidelberg, Germany doing a German Course. As a work experience, she made a project in a global company increasing the indicator of the Global Equipment Efficiency during a period of six months during 2019. She has worked throughout her life as a dance teacher in several dance academies. She has a certification of internal auditor ISO 9001:2015, and additionally, she has knowledge in Adobe Illustrator. She has taken online courses like Budgeting and Scheduling projects from the University of California Irvine, Fundamentals of Project Planning and Management from the University of Virginia, Initiating and Planning Projects from the University of California Irvine, Managing Project Risks and Changes from the University of California Irvine, Project Management: the basic for success from the University of California Irvine

Frida Sevilla is a Business Management Engineering student at Universidad de Monterrey (UDEM). Besides, she is in the Honors Program Leaders Plus at UDEM developing a social project. She has international experience from Charles University in Prague by being a participant in the Global Leadership Exchange program. She worked in a global company by increasing the indicator of Global Equipment Efficiency. Additionally, she worked as a sales assistant by developing an automated model for the administration of sales and a demand forecast model. Besides, in another company, she was the leader in the implementation of a new work cell and project leader of cost reduction. Frida has taken an Advanced Excel Workshop and Failure Mode and Effect Analysis Workshop at UDEM. She is certificated as an internal auditor of ISO 9001:2015. She has taken online courses like Design Thinking for Innovation from the University of Virginia, Fundamentals of the Quantitative Model from the Wharton University of Pennsylvania, Supply Chain Planning from Rutgers University, and Forecast Models for Marketing Decisions from Emory University, and Entrepreneurship: from the idea to the company, from Santander University.

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