RENMH
Team 15

Diversity Management Installation between Battery and Vehicle Assembly Lines

Oyak Renault Automobile Factories

Project Team
Zeynep Birsen
Fatih Musab Bozkurt
Arda Doğan
Gözde Gür
Berkay Kablan
Barçın Ozan
Bora Yıldırım
Industrial Engineering
Bilkent University
06800 Ankara

Industrial Advisor
Eyuphan Altunbay, Oyak Renault Automobile Factories,
Material Planning Engineer

Academic Advisor
Dr. Emre Uzun,
Bilkent University
Department of Industrial Engineering

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Abstract

This report contains information about Oyak Renault Bursa Factory and examines the synchronization between battery and vehicle production lines. The current battery production system is described and the problem is analyzed with data. A possible solution is suggested to improve the inventory model of the system by using a mathematical model. The model is verified for different scenarios. Finally, work packages and a detailed project plan are presented.

Keywords: Safety Stock, Automobile, Stock Management, Demand Uncertainty, Scheduling

Contents

1 Description of the System

Oyak Renault is an automobile factory established in 1969 to produce Renault cars under the partnership of Oyak and Renault. The capacity of the factory is 390,000 automobiles and 920,000 engines. In 2021, Oyak Renault manufactured 248,000 passenger cars which form 31.7% of total automobile manufacturing in Turkey. Oyak Renault is the leader in automobile export with a ratio 33.2% of Turkey's automobile exports. The number of automobiles that Oyak Renault exported in 2021 was 188,000. There are three models the facility manufactures: Clio, Clio E-Tech (hybrid), and Megane Sedan. In addition to this, the facility manufactures engines and mechanical parts such as gearboxes (Oyak, 2021). The company employs 6,935 people (Automobile Manufacturing Association, 2022). The company contains the departments of engineering, quality, manufacturing, financial and administrative affairs, logistics, human resources, purchase and communication (Ural, 2020). Oyak Renault has four components as the vehicle factory, the mechanical factory, Renault-Nissan-Mitsubishi Alliance International Logistics Center and R&D Center. The mechanical factory involves the production of chassis, gearbox, battery and engine.

High-tech batteries are assembled in the battery line for the Clio E-tech vehicles. Battery production rate is 18-21 units per hour, car production rate is 63-65 units per hour. Furthermore, unless an extraordinary situation occurs, there is a policy of the company such that a maximum of one of two consecutive cars can be manufactured as a hybrid. The production system consists of two main parts; the base battery assembly line and the U-conveyor assembly line. Firstly, batteries go through the base battery assembly line. All of the production and inspection processes occur in that single-line system. Batteries enter the system as a lot. Each lot consists of 18 batteries and these batteries have the same variety. Then for the next lot, other 18 batteries enter the single production line. The order of the batteries is preserved until they reach the inspection and battery charging stage. This stage consists of eight cells. After the inspection, the batteries that have any malfunction are extracted from the system. The batteries in good condition continue to the assembly by moving to the U-conveyor assembly line. The process of carrying between assembly lines is done by an operator through the instrument hydraulic lift. Then, the batteries are processed through the U-conveyor. At the end of the conveyor, there is a trolley which waits to be loaded with finished batteries and carries them to the vehicle production line. The battery production line can be seen in Appendix A.

2 Problem Analysis

In the base battery assembly line, there are two different battery types called 'Hitachi' and 'Sunwoda', and these batteries are referred as Type A and Type B respectively. The current production system uses these two types of batteries in the Clio Hybrid model (BJA). There is no such difference between battery types for the Clio Hybrid model. However, as of 2023, another type of vehicle (RJI) is planned to be produced and only Type B will be suitable for this new model. In 2023, while BJA will align with Type A and Type B, RJI will only align with Type B.

To provide synchronization between the production of batteries and vehicles, the current system will be modified by integrating an area called tristock area. Tristock area will enable holding inventory of batteries which is planned to be approximately 200 m^2. The modification starts with the construction of this area between the base battery production line and the U-conveyor to prevent delays in production caused by the mixed order problem among different battery types, defective batteries and demand uncertainty. For each battery, the charging and inspection durations might vary. Moreover, if the system detects any error within a battery, this battery is unusable. This means that the order of the batteries might change in this section, in other words, the first battery that enters the base battery production line may not come out first. Also, based on the analysis of the vehicle production data, it is observed that there are deviations between the planned number of vehicles to be produced and the number of vehicles produced. The production plan of the vehicles is finalized three and a half hours before the production. Yet, it takes approximately four and a half hours for a battery to reach the vehicle production line after the start of battery production. In order to prevent delays due to these problems, a stock of batteries must be kept in the tristock area. Batteries in tristock area will be stocked and separated according to their types. The location of the proposed tristock area can be seen in Appendix B. After the U-conveyor, the batteries are transported to the vehicle production line by trolleys. Each trolley carries eight batteries at a time. The loading and unloading of batteries are done from only one side. This means that the battery that enters the trolley first, leaves last. After the implementation of the tristock area, the batteries can be transferred to the U-conveyor in the inverse order so that the order in the trolleys will be aligned with the vehicle production line.

3 Literature Review

With the literature review, it is noticed that similar notions are discussed from different perspectives and our main goal is to find the most suitable approach to our problem.

There are two cases to be considered in safety stock determination; one is when the demand and lead time parameters are known while in other demand and lead time parameters are unknown, needed to be estimated. In the article Eppen and Martin (1988), both cases are discussed. The model focuses on determining a reorder point when both the demand and lead time variables are random. This situation fits with the Oyak-Renault project. After checking the data, we will analyze the parameters and then construct a safety stock according to them.

In inventory management systems, the aim is to prevent inventory stock-outs in case of demand and supply uncertainty. Our project focuses on determining the appropriate safety stock level for each battery type. The article Gonçalves et al. (2020) argues about dimensioning which is computing the necessary safety-stock levels. The article mentions different safety stock dimensioning strategies. The first one is stochastic models. In these models, queuing theory, Markov Chains and statistical theories are applied. This approach can be used in demand uncertainty. The second one is simulation-based models. This model is used for optimizing the model input, computing the parameters and creating sample scenarios. In this project, dimensioning will be used for calculating accurate safety stock levels under multiple uncertainties and simulation will be used for creating a sample scenario.

The other common method that is used in production is scheduling. Scheduling is the allocation of resources over time to satisfy some criteria optimally. In the article Graves (1981) production scheduling is explained through various scheduling problems by showing the differences between practice and theory. In the Oyak-Renault project, one of the possible solutions involves scheduling in order to minimize the stock. The scheduling will be performed in order to calculate an initial time to start production to minimize the stock needed. This article provides a review of the production scheduling theory and also provides observations on the practice that will be used in the project.

In addition to that, in order to build a dynamic system which works based on the availability of the inventory, the article Takeda-Berger et al. (2022) is approaching an automobile manufacturing system with a reactive scheduling method. This reactive scheduling method combines the manufacturing stages by performing optimization on job sequencing. Then, the optimized model is evaluated and analyzed with a simulation method to test the reliability of their solution method. In this project, after scheduling and minimizing the stock, a simulation model will be used to evaluate the results we obtained.

In order to decide the review system that is going to be used in this project, continuous review policy and periodic review policy are compared to understand the most applicable policy. In the article Rizkya et al. (2018), to control stock levels, continuous and periodic review policies are examined. Considering the formulas and explanations of both policies, the periodic review policy can be considered inapplicable in the Oyak Renault project since the stock level can drop and remain less than the planned number to be kept in the stock until the next period in this policy. However, the continuous review policy fits the project, since it keeps a constant stock level for the changing demand. Therefore the continuous review policy is applied in the stock-level decisions.

In the article Soman et al. (2006), both make-to-stock and make-to-order policies for production are defined. Since the system has random demands, these production methods are combined in order to avoid stock-outs in the system.

The main goal of this paper is to decide the minimum amount of stock to be kept according to random demand. In the Oyak Renault project, a similar system is used which tries to minimize the stock to be kept in the tristock area while trying to synchronize the battery production line and vehicle production line.

4 Proposed Solution Strategy

4.1 Critical Assumptions

Considering the battery production line, some numerical and non-numerical information will be based on assumption for the sake of the implementation of the project. The first assumption made is about the production type of the battery line. Oyak Renault uses aggregate production planning since both types of batteries can be integrated into the hybrid car. Yet, their production planning will be assumed to be disaggregated so that in the long run, as a company will have diversity in batteries, battery production will not be mixed within diversities. Another assumption is about the production rate of batteries. Batteries in Oyak Renault are produced within a range of 15-21 batteries per hour. Other than these, as batteries are started to be produced until they enter the charging process, they undergo some assembling processes.

Additionally, the company gave us the daily production quantities of hybrid vehicles between the date of 10.01.2022 and 10.10.2022. Our model works based on the daily demand quantities to be entered. The amount of incoming daily demand is uniformly divided into the 24 hours in which the factory produces. In other words, it is assumed that the incoming daily demand amounts are uniformly distributed over the hours.

The capacity of the tristock area is assumed to be a maximum of 320 batteries. Another assumption made is that there are no human errors throughout the assembly and transportation processes of batteries. There might be rare human errors that cause negligible waste of time. That is why we are assuming there will be no idle time while employees work.

In both mixed lot and lot production, it is assumed that safety stock can be refilled immediately by inserting a battery into the production line. In lot production, this will be done by inserting a lot with one battery size.

4.2 Major Constraints

There are some exact specifications and restrictions given by the company that must be complied with during the project. One of the first constraints is the tristock area which will be used to keep battery stocks. The area determined by the company cannot exceed 200 m2. Another constraint is about storing batteries into the tristock area. Batteries cannot be stocked on top of each other since this application will require a multistory storage system which costs much more than a regular storage system. It should be considered that the arrival of a battery to the vehicle production line takes five hours after initialization of its production. Also, the capacity of the battery production line is another constraint. According to the information given by the company, the maximum capacity of battery production is 26 batteries per hour. For the vehicle production line, there are more constraints affecting the battery line. The first one is the capacity of the line. Oyak Renault can produce up to 65 vehicles per hour. Moreover, there is a policy called two for one which obliges the production line to produce a maximum of one hybrid vehicle out of two vehicles consecutively. The company embraces lot production which provides batteries to enter the process with a group of 18. Also, the company does not let different battery types enter the same lot.

4.3 Objectives

The project's main objective is to define a safety stock level and production plan for each type of battery. After inputting the demand each day, the stock level and proper production plan for each type of battery are determined. Thus, the appropriate production plan for batteries will be implemented.

4.4 Solution Approach

By using a mathematical model, it is aimed to create a synchronized production schedule that will minimize the inventory allocated at the tristock area in each period. In this mathematical model, safety stock will be used to prevent the possible stock-outs that may lead to an interruption in the production line.

4.4.1 Conceptual Method

The proposed solution for the problem consists of mathematical modeling. This mathematical model is prepared for hourly periods. The total inventory level in the tristock area is minimized at the end of each period. While applying the principle of safety stock, the continuous review policy is integrated. The flowchart of the conceptual model is given in Appendix C.

4.4.2 Mathematical Model

In this model, the vehicle production schedule is taken as input. By using this information, a battery production schedule is created as an output. The input consists of the demand of the vehicle assembly line. The output consists of 24 periods in which each period lasts an hour. Based on the company's expectations, the model assigns the number of batteries that should be produced for each type in each period to satisfy the upcoming demands while minimizing the inventories in the tristock area. For this reason, in the objective function, the inventory level for each battery type in each period is minimized. The mathematical model is shown below:

Sets

I = Battery type set

$J =$ Vehicle type set

$T =$ Period set

Parameters

$Acap_i =$ Tristock capacity for battery type i such that capacity does not exceeding 320

$Bcap =$ Battery production capacity

$$y_{ij} = \begin{cases} 1, & \text{1, if battery } i \text{ is compatible with car } j \\ 0, & \text{otherwise} \end{cases}$$

$I_i =$ Initial inventory level for battery type i

$D_{jt} =$ Demand of vehicle type j in time t

Decision Variables

$P_{it} =$ Produced amount of battery type i in time t

$I_{it} =$ Inventory level of battery type i in time t

$G_{ijt} =$ Number of battery type i produced for vehicle type j in time t

Model

$$\text{minimize} \qquad \sum_{i \in I} \sum_{t \in T} I_{it}$$

subject to

$$I_{it} \leq Acap_i \qquad \forall i \in I, t \in T \tag{1}$$

$$\sum_{i \in I} P_{it} \leq B_{cap} \qquad \forall t \in T \tag{2}$$

$$I_{it+3} = I_{it+2} - \sum_{j \in J} G_{ijt+5} + P_{it} \qquad \forall i \in I, j \in J, t \in T \tag{3}$$

$$\sum_{i \in I} y_{ij} G_{ijt} \leq D_{jt} \qquad \forall j \in J, t \in T \tag{4}$$

$$I_{it} \geq 0 \qquad \forall i \in I, t \in T \tag{5}$$

$$P_{it} \geq 0 \qquad \forall i \in I, t \in T \tag{6}$$

$$G_{ijt} \geq 0 \qquad \forall i \in I, j \in J, t \in T \tag{7}$$

The detailed explanation of the constraints is shown below:

Constraint 1 ensures that for any battery type, the number of batteries allocated in the tristock area can not exceed the tristock capacity allocated for that battery type. This tristock area capacity is provided by the company.

Constraint 2 ensures that for any battery type, the produced number of batteries cannot exceed the battery production rate.

Constraint 3 is the inventory balance constraint. It shows that the ending inventory is the difference between the existing batteries in the tristock area and the current battery demand. The existing batteries currently in the tristock area are equal to the sum of the remaining batteries from the previous period and the batteries produced three periods ago. Since it takes three hours for a battery to reach the tristock area and complete the battery production line, the batteries that started to be produced three hours ago affect the current period. Also, it takes two hours for a battery to reach the vehicle assembly line from the tristock area. For this reason, the demand of the next two hours is subtracted when calculating the current inventory level.

Constraint 4 sustains that the number of required batteries for each type is determined by the vehicle demand. Since the batteries are unique to different types of vehicles, a binary parameter is used to match the batteries with vehicles. This constraint ensures that the battery compatible with the demanded vehicle is determined and that a compatible battery is produced with respect to the incoming vehicle demand.

The remaining constraints indicate non-negativity.

4.4.3 Lot Extension

The company currently produces lots. In order for the company to use the model before switching to the mixed-lot production, an extension of the model is formed such that production is done in lots in which each lot consists of 18 batteries. For that model, the periods are taken as 45 minutes. Accordingly, the output consists of 32 periods.

Regarding of this information, the mathematical model for lot production is shown below:

Sets

I = Battery type set

J = Vehicle type set

T = Period set

Parameters

$Acap_i$ = Tristock capacity for battery type i such that capacity does not exceeding 320

$Bcap$ = Battery production capacity

$$y_{ij} = \begin{cases} 1, & \text{1, if battery } i \text{ is compatible with car } j \\ 0, & \text{otherwise} \end{cases}$$

I_i = Initial inventory level for battery type i

D_{jt} = Demand of vehicle type j in time t

Decision Variables

P_{it} = Produced amount of battery type i in time t

I_{it} = Inventory level of battery type i in time t

G_{ijt} = Number of battery type i produced for vehicle type j in time t

$$Z_{it} = \begin{cases} 1, & \text{1, if battery } i \text{ is produced in time } t \\ 0, & \text{otherwise} \end{cases}$$

Model

$$\text{minimize} \qquad \sum_{i \in I} \sum_{t \in T} I_{it}$$

subject to

$$I_{it} \leq Acap_i \qquad \forall i \in I, t \in T \tag{1}$$

$$\sum_{i \in I} P_{it} \leq B_{cap} \qquad \forall t \in T \tag{2}$$

$$I_{it+4} = I_{it+3} - \sum_{j \in J} G_{ijt+6} + P_{it} \qquad \forall i \in I, j \in J, t \in T \tag{3}$$

$$\sum_{i \in I} \sum_{j \in J} y_{ij} Z_{it} \leq 1 \qquad \forall t \in T \tag{4}$$

$$\sum_{i \in I} y_{ij} G_{ijt} \leq D_{jt} \qquad \forall j \in J, t \in T \tag{5}$$

$$P_{it} \leq 18 Z_{it} \qquad \forall i \in I, t \in T \tag{6}$$

$$I_{it} \geq 0 \qquad \forall i \in I, t \in T \tag{7}$$

$$P_{it} \geq 0 \qquad \forall i \in I, t \in T \tag{8}$$

$$G_{ijt} \geq 0 \qquad \forall i \in I, j \in J, t \in T \tag{9}$$

$$Z_{it} \in \{0, 1\} \qquad \forall i \in I, t \in T \tag{10}$$

The detailed explanation of the constraints is shown below:

Constraint 1 ensures that for any battery type, the number of batteries allocated in the tristock area does not exceed the tristock capacity allocated for that battery type. This tristock area capacity is provided by the company.

Constraint 2 ensures that for any battery type, the produced number of batteries cannot exceed the battery production rate.

Constraint 3 is the inventory balance constraint. It shows that the ending inventory is the difference between the existing batteries in the tristock area and the current battery demand. The existing batteries currently in the tristock area are equal to the sum of the remaining batteries from the previous period and the batteries produced four periods ago. Since it takes three hours for a battery to reach the tristock area and complete the battery production line, the batteries that started to be produced four periods ago affect the current period. Also, it takes two hours for a battery to reach the vehicle assembly line from the tristock area. For this reason, the demand for the next two 45-minute period is subtracted when calculating the current inventory level.

Constraint 4, 5 and 6 ensures that only one lot, which consists of one type of battery compatible with vehicle type j, can be produced in each period such that the vehicle demand is met.

The remaining constraints indicate non-negativity and binary variables.

4.4.4 Safety Stock Calculation

The safety stock level is calculated as follows:

The company provided two data sets; the planned production and the actual production amounts. There is a deviation between the planned production and actual production amounts. In addition, 2% of batteries that enter the battery production line are defective. A safety stock has been developed against these errors and differences in demand.

First of all, the deviation between the actual and planned production amount is fitted to an empirical distribution. Then, the service level is determined as 95% and safety stock is calculated accordingly as 0.29 per period. Also, the defective batteries are taken into consideration as 0.52 per period. The probability of getting a non-defective battery after the detection of the first defective battery is calculated by using a cumulative geometric distribution. Consequently, it is obtained that a battery has a chance to be defective in two consecutive periods but it is highly unlikely to be non-defective in its third period. The outcomes of these calculations are used in the derivation of the safety stock quantity as five per period. A portion of the battery production rate is allocated to refill the safety stock quantity by decreasing the rate of battery production for every period. For every period, the battery production rate is decreased by the number of battery types. This way, when the battery is used from the safety stock, the safety stock can be refilled immediately.

For the lot production, the safety stock is calculated again. A period is assumed as 45 minutes. This way, the total periods in a day become 32. This affects the safety stock that is caused by the deviation of actual and planned production is calculated again as 0.22 per period. Consequently, the safety stock for lot production is found as four per period. Also, because a lot consists of just one type, the rate of battery production is decreased by one for every period.

4.4.5 Solution Method

In the implementation of the model, the Excel Solver is used. The model is tested on the three days in which the demand coming from the vehicle assembly line is maximum. There are five inputs in the model. The first one is the daily demand which is uniformly distributed over periods. Also, a vehicle demand weight parameter is inserted which determines distribution of demand over vehicle types. The third one is the initial inventory amount for each type of battery. The fourth input is the produced amount of each type of battery for three periods prior to the beginning of the model. Lastly, a matrix indicating which type of batteries are compatible with which types of cars. In order to supply the given demand, the model solves which battery should be used in which amount in which period.

4.5 Verification

4.5.1 Maximum Demand

The factory has a maximum capacity of 67 vehicles in an hour and because there can be no backlogs, the need for 67 vehicles must be met every hour. With maximum demand which is 32 and maximum production which is 23, With an initial inventory of 60 for each battery type, the model runs smoothly. In this case, the maximum inventory level in the tristock area becomes 171. The inventory levels below 180 do not satisfy the system because of the production capacity. In the case of 150 inventory as initially, the system wants to catch up with producing 53 batteries in total for the first period which exceeds the capacity (23). In order to solve this problem, a minimum of 180 batteries must be in the tristock area without starting production.

4.5.2 One Type of Battery Production

With the upcoming new battery type, the factory should be answering the production of only one battery type for 24 periods. Up to 23 demands for every period, the model runs smoothly without any initial inventory. In this scenario, because every demand is satisfied perfectly, the inventory level in the tristock area is fixed at zero. When the demand is increased with zero inventory, the model becomes infeasible. In order to prevent this, the inventory level can be increased according to the demand.

4.5.3 Machine Breakdown

For an extreme case, we wanted to try our model for a possible machine breakdown for one shift. To obtain this, the production of the shift in the middle of the day which contains eight periods is equalized to zero. In these kinds of situations, the safety stock can be used and replenished without any complications. However, we can say that with the initial inventory level of 11 for each battery type, the system can fulfill the demands.

4.5.4 Decrease in Tristock Area

Because one of the main goals in this project is to minimize the tristock area, as another scenario, we want to consider the case that half of the tristock area and eventually, the upper bound for inventory decreases. When the upper bound becomes 160 and the demand is maximum (32), the model becomes infeasible. To overcome this problem, the production capacity which is fixed at 23 can be relaxed. When the production capacity becomes 26, the maximum level of inventory in tristock becomes 120 which is even less than 160. The initial inventory is 40 for every battery type and the production is maximum for every period.

4.5.5 Maximum Demand for Lot Production

For lot production, the maximum demand for a period is 24. The model works smoothly when there is an initial inventory of 59 for every battery type to meet the maximum demand for every period. In this case, tristock below 177 below makes the model infeasible because starting from the fifteenth period, the demand started not to be satisfied. In order to solve this problem, a minimum of 177 stocks must be in the tristock area without starting production.

4.6 Validation

The validity of the model is evaluated by inputting vehicle production demand which is provided by the company to Excel solver. The data set for the last year (2022) is completely given by the company and the maximum demand amount in consecutive three days (August 22 - August 24) is picked from this data set. Since the maximum vehicle production for a day is 402, the demand is assumed to be distributed uniformly over a day as 17 vehicles per hour. In such situation, there are 397 batteries produced per day and demand can be met. With this change, different starting inventory levels were tested in the validation process. With an inventory total of 11, the battery production continues without any breakouts and satisfies all the vehicle demand. In this scenario, the maximum level of inventory in tristock area becomes 18. It is observed that with the provided schedule of the vehicle production, the tristock area was able to provide enough capacity including the safety stock level.

5 Outcome and Deliverables

5.1 Outcome

There will be several outcomes of the project. Initially, an inventory policy that involves holding safety stock will be determined to supply any kind of demand pattern and avoid stockout situations. Decision support for regulating the stock level and dynamic stock tracking will be accomplished.

5.2 Deliverables

To display the results of the mixed lot production and lot production model, a user interface is created via Jupiter. This interface is a tool for people to plan battery production level to synchronize with the vehicle assembly line. First, a login page welcomes the user which is presented in Appendix D. Users must enter their username/e-mail address and password to proceed to the “Choice of action” page as it can be seen in Appendix E. On that page, there are three options ordered as battery production plan, safety stock level and change parameters respectively.

As the battery production plan option is determined by the user, the user interface requests necessary information from the user, which can be observed in Appendix F. User has to input values for the initial inventory of each type of battery. In addition to the initial inventory values, users must input the amount of batteries to be produced for each battery type at times 1, 2, and 3. After all inputs are done, the user can proceed to the next screen which is available in Appendix G. In this screen, the user needs to upload the Excel file that contains the periodic demands of each battery type. This file indicates the total demand for each battery type, demand should be satisfied at the end of the day. Since initial inventory values are entered before, all needed information is entered to display the output which is the battery production plan in hours, periods. The safety stock level option is not ready to be presented yet, but the plan for this screen is the user will input the defect rate of batteries in the battery production line and service level as a result safety stock level of each battery type will be presented as output. Lastly, if there will be any change in battery or vehicle quantity or any change in capacity, the change parameters option will be available to use. These three options support the mathematical model of mixed lot production and run the user interface with this model’s principle.

5.3 Implementation Plan

In order to conduct a pilot study, the user interface is provided to the company with an explanatory booklet to help with implementation and ensure easy usage. Then, to integrate our approach into the company’s existing system, a pilot study is conducted with the user interface by the company. For the utilization of the user interface, the company is requested to determine the initial inventory level, production quantity, and vehicle production amount in a formatted Excel file. The user interface extracts the necessary information from these Excel files provided by the company to ensure alignment between the production plan and the data. Once the data entry process and the setup procedure are complete, the user interface is prepared for the pilot study and the company is asked to conduct the pilot study for a full day.

When the pilot study was conducted, it tested two points. Firstly, it evaluated the functionality of the user interface and its ability to effectively utilize the model with the provided data. Secondly, the efficiency of the production plan is checked through observation by the company. Although the current battery production may not be synchronized with the vehicle assembly line, the tristock inventory level enabled synchronization between the two. The company informed us that the user interface was working properly and the synchronization was successfully done.

In the implementation, the company utilized daily battery assembly plans and maintained safety stock levels as indicated in the user interface findings. Although there is currently no tristock area in the system, the implementation was carried out using the existing capacity of the battery stocking areas surrounding the battery assembly line. Therefore, in the current system, the tristock area's capacity will be 44, as it yielded efficient results during the pilot study. In the coming years, the company has plans to introduce a larger tristock area, and they will have the ability to update the capacity of that area within the user interface.

5.4 Benchmarking and Benefits to the Company

After validation, we can compare the current system's result with the model's output. The model aims to minimize stock levels and synchronize the battery and vehicle production line. The stock level is a significant performance measure, with a preference for the minimum level being the ideal KPI. Parallel to that, the aim of this project is to synchronize the vehicle production line and base battery assembly line with a minimum number of stocks, ensuring uninterrupted operation in case of fluctuations or radical changes in demand. The tristock area's construction increased the available stock area by eight times, enabling uninterrupted production. Previously, despite maintaining maximum stock, the vehicle and battery production lines could not be fully synchronized. Previously, the battery production line could only satisfy the maximum of 552 vehicles per day. However, the production plan now enables synchronization by utilizing the planned production data in advance of the actual production. This way the battery production line can satisfy the demand of 576 vehicles per day. This represents a 4.1% improvement over the old system. Moreover, with the help of the user interface, the production plan and the required stock level will be displayed. Currently, the company does not have a variety regarding batteries since both Hitachi and Sunwoda type batteries can be installed on Clio Hybrid. However, the company plans to have different types of batteries in the long run. Therefore, the expected benefits to the company also includes managing the variety in production by utilizing the user interface.

6 Conclusion and Future Work

In conclusion, the proposed solution for battery production planning at Oyak Renault, based on mathematical modeling, is designed to address the challenges of managing stock levels, demand uncertainty, and production synchronization in the battery production line. The model aims to minimize inventory levels, prevent stock-outs, and ensure uninterrupted production in the tristock area. By considering factors such as demand, production capacity, and safety stock requirements, the model provides a synchronized production schedule that optimizes production efficiency. The implementation of the production plan based on the proposed model has already yielded positive outcomes, including a 4.1% improvement in the battery production line's capacity to satisfy demand. The user interface provided with the model has also improved visibility and control over the production process, leading to better decision-making and production planning.

Furthermore, the proposed model has the potential to support future plans for managing variety in production. The company intends to build a tristock area where safety stocks will be stored. Based on the battery demand for each type and service level percentage, the user interface will display the necessary safety stock level that needs to be prepared in the tristock area for each day. Through this project, company workers can follow the user interface to determine the appropriate safety stock value for each day. The user interface also features an "parameters" option, which allows company workers to adjust the numbers for vehicle or battery types and modify the compatibility matrix that shows which battery type can be integrated with which vehicle type. This parameter option ensures that the model can adapt to new conditions and potential future changes at Oyak Renault Bursa Factory.

By improving stock level management and production synchronization, the model has significantly increased operational efficiency. Overall, the proposed solution based on mathematical modeling offers a promising approach to tackle the battery production planning problem at Oyak Renault, providing tangible benefits in terms of improved production efficiency, stock level management, and production line synchronization.

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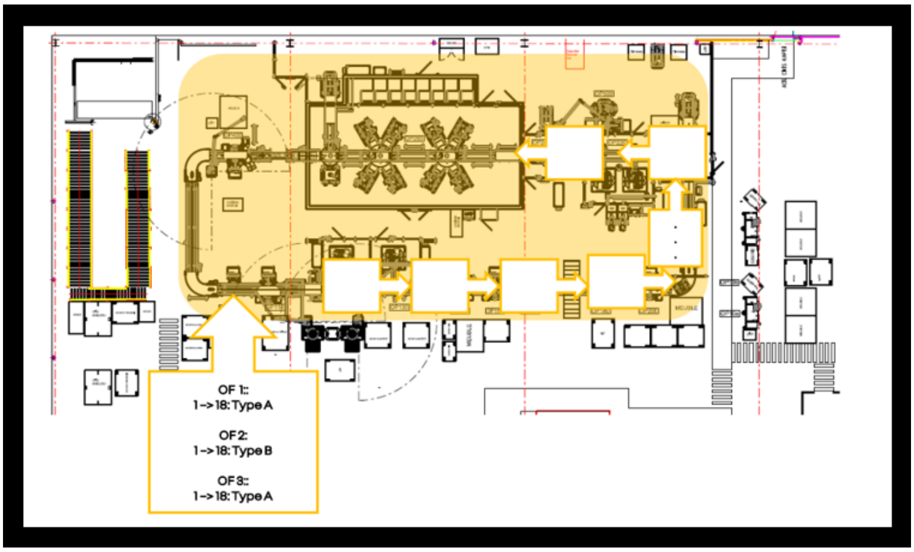
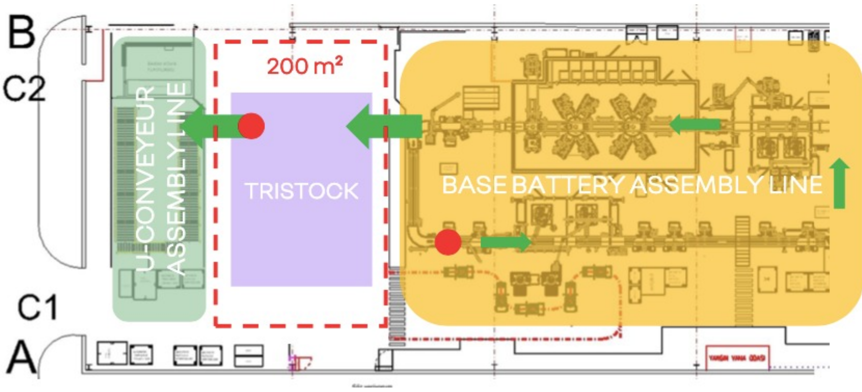
Appendices

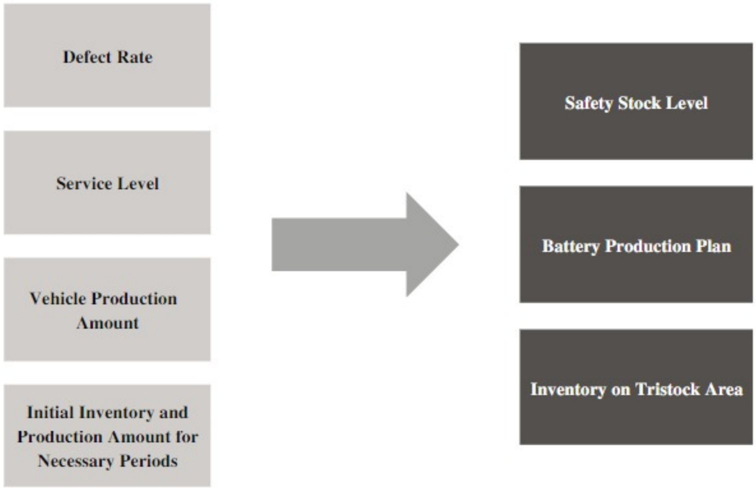
Appendix A: Battery Production Plant



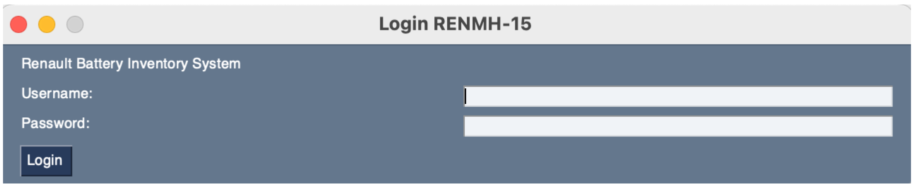
Appendix B: Tristock Location



Appendix C: The Flowchart of the Conceptual Model

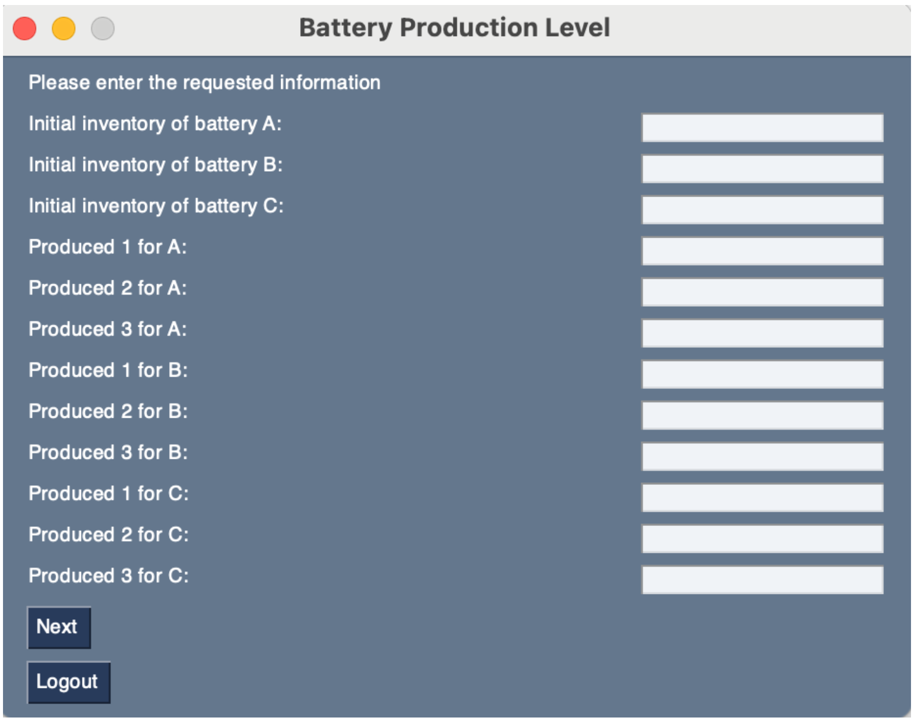


Appendix D: User Interface Login Window

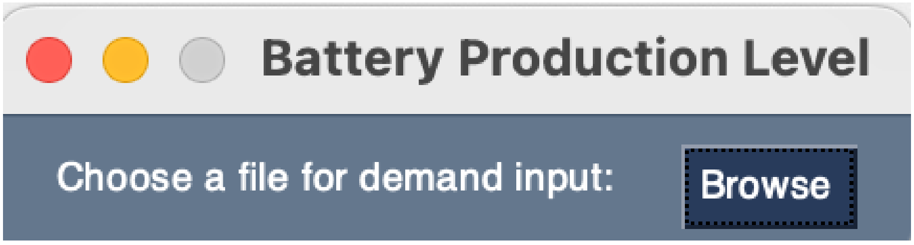


Appendix E: User Interface Choice of Action Window

Appendix F: User Interface Input Step 1



Appendix G: User Interface Input Step 2



Appendix H: The Gantt Chart of Work Packages