Optimizing the S.S.A.Ratio Level Indexes of the PBS process in Nissan's Production Plant

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Improvement of S.S.A.R. in the PBS process

Executive Summary

The aim of this paper is to review the significance of Scheduling and Sequencing, this have an effect on the Scheduled Sequence Achievement Ratio (S.S.A.R.) rating in the Painted Body Storage (PBS) facility in Nissan's production plant situated in Rosslyn. Nissan uses the S.S.A.R. rating to measure how the cars keep their scheduled sequence throughout the manufacturing process.

This paper reviews methods for solving car sequencing problems, the first methods consists of Variable Neighbourhood Search, the second method of Ant Colony Optimization and the last method uses Greedy Heuristics. These methods are evaluated in terms of the problem we have at the PBS. A Heuristic is developed as a conceptual solution to address the sequencing problem at the PBS Facility.

The objective of the Heuristic is to search for the minimum difference in Douki Seisan Number between the vehicles that is last in each lane 1 → J and the vehicle that needs to be committed into the lanes. This Heuristic is implemented at the decision nodes in the PBS Facility.

Results suggest the Heuristic have a greater impact on achieving better S.S.A.R. Ratings at the decision nodes than the current way of decision making that is based on the type of model.

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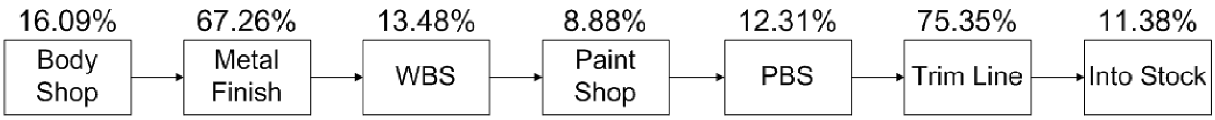
1 Introduction

Nissan experiences problems with S.S.A.Ratio (Scheduled Sequence Achievement Ratio) of the cars that are not kept in the original order that the process of the cars started within each process. This leads to cars staying in the process longer than what is intended, getting older and subsequently at risk of either secondary damage or relevant parts pilferage.

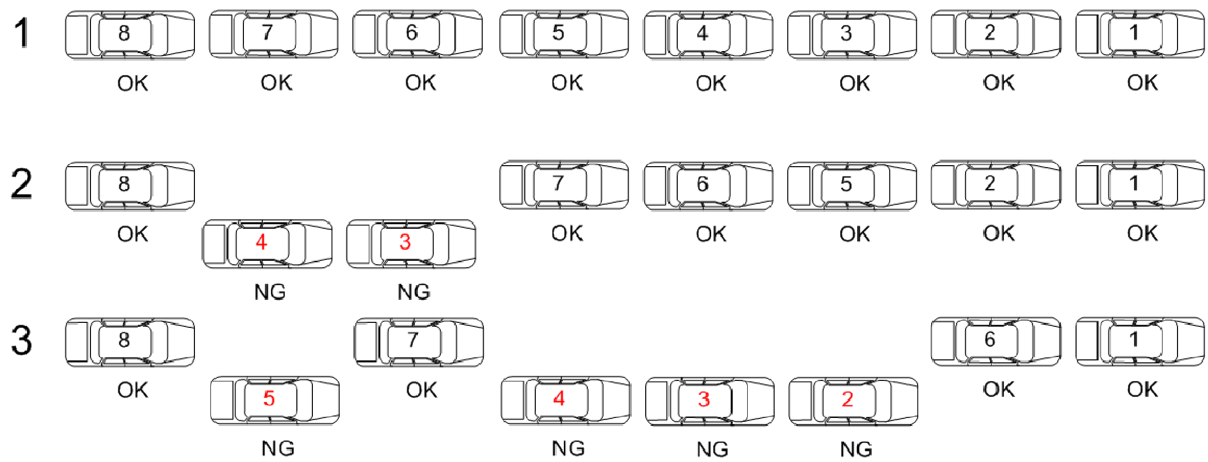
Figure 1: Flow Diagram of Processes with respective S.S.A.Ratio ratings



1.1 S.S.A.Ratio

Scheduled Sequence Achievement Ratio (S.S.A.Ratio) shows how much vehicles could keep scheduled sequence in actual schedule. A vehicle is OK when it's not overtaken by another vehicle and NG (No Go) when it has been overtaken by one or more vehicles (Nissan Motor LTD., 1998).

Figure 2: Illustration of Sequence



Calculation: S.S.A.R (%) = (OK Vehicles / Total Number of Vehicles Processed) * 100

1: S.S.A.R = 8/8 * 100 = 100%

2: S.S.A.R = 6/8 * 100 = 75%

3: S.S.A.R = 3/8 * 100 = 37.5%

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2 Project Aim

The aim of the project will be to improve the S.S.A.R. ratings at the PBS (Painted Body Storage) with Industrial and System Engineering methods such as linear programming that will address a car sequencing problem.

3 Project Scope

Looking at the system as a whole the Paint Shop S.S.A.Ratio rating is the lowest. The Paint Shop is referred to as a "Black Box" and is a problem on its own which will take a separate project to address. However CCR (Centre Control Room) and the Production Department are currently rushed in small activities that can provide ongoing improvement to the current S.S.A.R. achievement.

Figure 3: Illustration of S.S.A.Ratio ratings

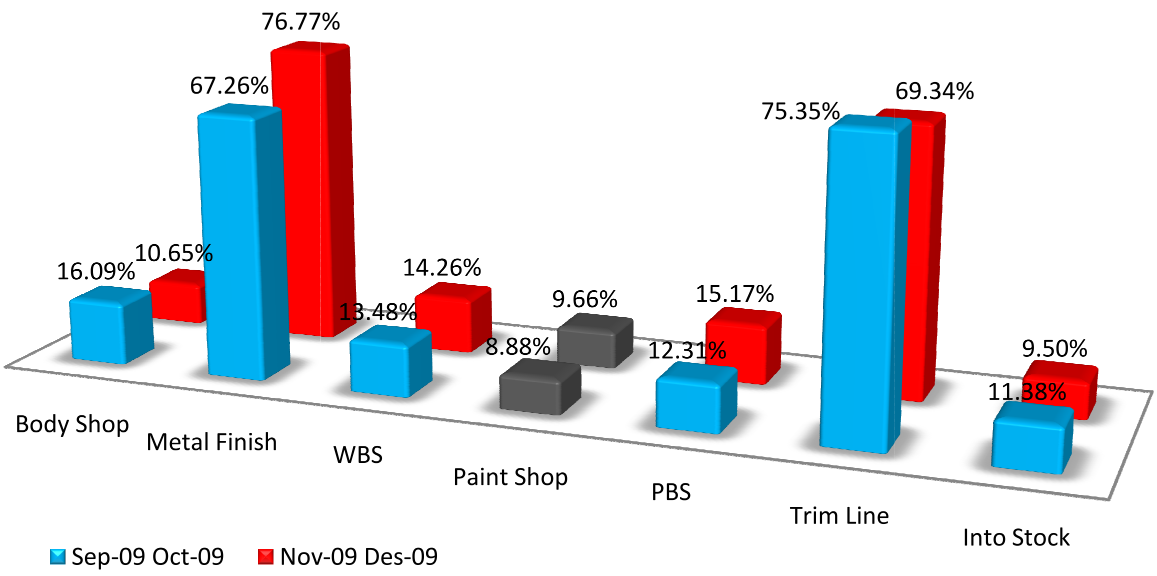

Figure 3: Illustration of S.S.A.Ratio ratings shows that Into Stock, PBS and WBS are the processes that follow the Paint Shop in achieving the lowest S.S.A.R. Ratings. This project

will therefore specifically focus on the PBS process as this shows the most potential for improvement.

PBS receives the painted bodies from Paint Shop and separates the models X11J, X11C, N11J, U90 and B90 for the Multi Model Committed Line and the QW and D22 for the QW Committed Line. The models QW and D22 are stored in lanes 1-14 and the models X11J, X11C, N11J, U90 and B90 are stored in lanes 15-32, Figure 26: PBS Facility Layout.

At present the cars are stored in the storage lanes by the operator by means of model type e.g. QW and D22 have different model types like; a NP 300 Hardbody Double cab 2.5TDi Hi-Rider (Model code - K24) or a NP300 Hardbody Single cab 2000i 16V SWB (Model code - K16) and not by their Douki-Seisan number. The Douki-Seisan number is assigned to a paper car that is created at the beginning of the manufacturing process when the sequence for the cars is planned.

Storing the vehicles by means of their model type has the affect of the vehicles being taken out of their initial sequence and thus affecting the S.S.A.R. ratings negatively. The vehicles are then selected by model type to be committed to the Trim Line, here again the vehicles are committed by means of model type and not their initial sequence.

4 Literature Review

Flexible manufacturing processes have been introduced to be able to produce a variety of models of a basic product. Mixed-Model lines aid in achieving a wider range of products than just the traditional method of single product assembly. A Mixed-Model line does however have to handle more variability in terms of the work load and material requirements making planning an essential part (Fliedner, 2008). Planning the production schedule and the sequence in which the products are manufactured will hinder that the process becomes overloaded.

4.1 Scheduling

Scheduling is a decision making process that is used on a regular basis in manufacturing and services industries. It deals with the allocation of resources to tasks over given time periods and its goal is to optimize one or more objectives (Pinedo, 2008).

In many instances there are a limited amount of resources available for the production of units or task that needs to be performed. Resources are required to carry out a task, e.g. People, Machinery, Funding and Facilities. Task is the action that utilizes the resource in order to create a product or service this needs to be accomplished in a period of time.

4.1.1 Forward and backward Scheduling

Forward scheduling, schedules the tasks forward in time that need to be completed for an order. Forward scheduling will typically be able to tell you when the earliest time will be for an order to be completed. Backward scheduling takes a due date in the future and schedules the tasks backward in time, hence indicating when an order should start to be completed at the specified date (Chase, 2007).

4.1.2 Scheduling in Manufacturing

Michael Pinedo (Pinedo, 2008) illustrates in Figure 4 that throughout the manufacturing system scheduling plays a major part. In the beginning capacity planning allocate orders and resources to the specified manufacturing bays. Scheduling then determines the sequence in which all the orders will be performed making use of the preferred Rule of Sequencing, explained later in the section. The scheduled orders are then dispatched in their respective sequence. Then Shop-floor management review and control the progress of all the orders and attend to or reschedule the orders that are lacking.

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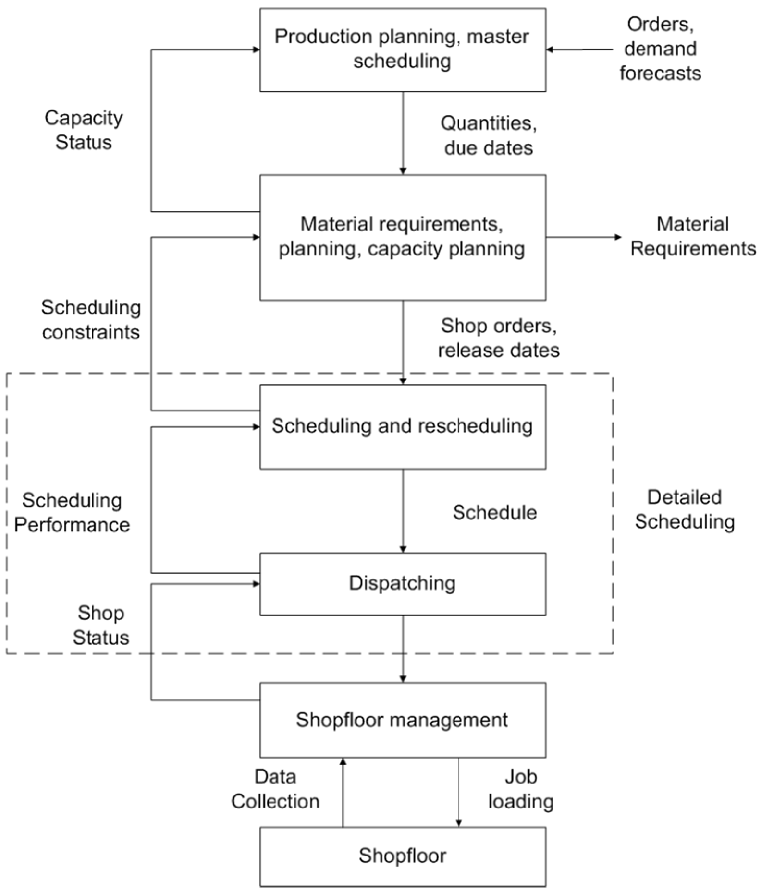
Figure 4: Information flow diagram in a manufacturing system



In Operations Management for a Competitive Advantage (Chase, 2007) describes the different types of manufacturing processes that uses different types of scheduling approaches. These manufacturing processes and scheduling approaches follow.

Table 1: Manufacturing Processes and Scheduling Approaches

Type	*Product*	*Characteristics*	*Typical Scheduling Approach*
Continuous Process	Chemicals, steel, wire and cables, liquids and canned goods.	Full Automation, low labour content in product costs, facilities dedicated to one product.	Finite forward scheduling of the process; machine limited.

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High-volume manufacturing	Automobiles, telephones, fasteners, textile, motors, household fixtures.	Automated equipment, partial automated handling, moving assembly lines, most equipment in line.	Finite forward scheduling of the line (a production rate is typical); machine limited; parts are pulled to the line using just-in-time (kanban) system.
Mid-volume manufacturing	Industrial parts, high-end consumer products.	GT cells, focused mini factories.	Infinite forward scheduling, typical: priority control; typically labour limited, but often machine limited; often responding to just-in-time orders from customers or MRP due dates.
Low-volume job shops	Custom or prototype equipment, specialized instruments, low volume industrial products.	Machining centres organized by manufacturing function (not in line), high labour content in product cost, general purpose machinery with significant change over time, little automation of material handling, large variety of product.	Infinite forward scheduling of jobs: usually labour limited, but certain functions may be machine limited, priorities determined by MRP due dates.

4.2 Sequencing

Sequencing is the order in which task are performed in a manufacturing process (Conway, 2003). Sequencing can be done by taking information regarding processing time, due date or arrival of order to determine in what order the task will be performed (Chase, 2007).

4.2.1 Rules for Sequencing

Table 2: Priority rules for Sequencing.

Rule	Abbreviation	Description
First-come, First-served.	FCFS	If order arrives first it is attended to first.
Last-come, First-served.	LCFS	If order arrives last it is attended to first.
Earliest due date first.	EDD	Order with the earliest due date is attended to first.
Critical Ratio.	CR	Orders with smallest CR is attended to first, CR is calculated by taking the difference between due date and current date divided by the number of working days left.
Slack time remaining.	STR	Orders with lowest STR are attended to first, STR is calculated by taking the time remaining before the due date and subtracting the processing time that remains.
Slack time remaining per operation.	STR/OP	Orders with the lowest STR/OP are attended to first; STR/OP is calculated by dividing the STR by the number of remaining operations.
Shortest operating time.	SOT	Order with the shortest operating time is run first.
Random		The operators select whatever order he wants to do.

4.3 Scheduling and Sequencing Problems

Car sequencing problems are a common problem in the automobile manufacturing industry. Multi-model lines are used to be more cost effective but this makes sequencing the cars more complex as various models have various options fitted to them. These options have to be fitted at the various bays on the assembly line adding time constraints at each bay (Prandtstetter, 2008). More variety of models leads to a large variability of materials and a greater workload required that has to be managed in a way to meet the material demand (Fliedner, 2008).

The ROADEF'2005 challenge introduced an additional constraint to the original car sequencing problem. This constraint is based on minimizing the paint changes in the Paint Shop. Each time a colour in the Paint Shop is changed the spray gun has to be cleaned taking up time and paint solvent.

Various methods have been developed to address car sequencing problems, these methods range from Variable Neighbourhood search heuristic to Greedy heuristics and the Branch and Bound method.

4.3.1 Methods

4.3.1.1 Variable Neighbourhood search heuristic (VNS)

Alexandre Joly and Yannick Frein (2008) addressed this car sequencing problem by proposing and comparing various methods. One of the methods they proposed was the Variable neighbourhood search heuristic (VNS).

VNS generates solutions through application of elementary transformation starting at the initial solution. Each solution is then evaluated with the objective function, and if the function cost of the solution is lower it replaces the first solution. VNS depend on an initial solution and a neighbourhood structure (Joly, 2008).

Initial Solution

The Initial Solution is the state in which the cars are at the start of the application of the transformations. Alexandre Joly and Yannick Frein (2008) tested three initial solutions, these solutions comprised of, SAS a strategy that favours the respect of the assembly shop objectives, SPS a strategy that favours the respect of the paint shop objectives and a Random solution.

Neighbourhood

The neighbourhood structure requires two cars to be transformed. Transformation can be accomplished by means of Swap, Movement, Reverse and any randomly chosen one of the three transformations structures mentioned.

Table 3: Neighbourhood Transformation Operators.

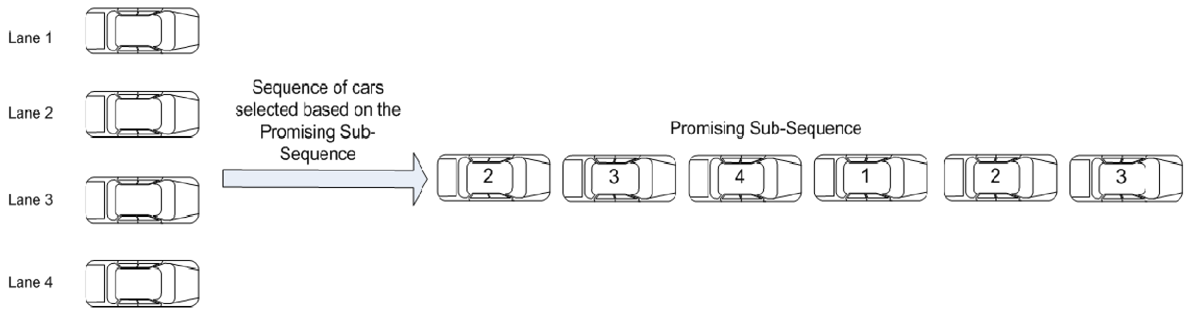
Transformation operator	*Description*
Swap	Swapping the two cars with each other.
Movement	Moving car from initial position to another position.
Reverse	A part of the sequence is reversed.
Random	Any of the above randomly chosen

4.3.1.2 Ant Colony Optimization (ACO)

Ant colony optimization (ACO) makes use of artificial ants to find good paths, these paths are based on the minimum cost path for the car sequencing problem. In real life an ant uses pheromone trails that are laid by other ants of the colony to determine the path he will follow. With this indirect way of communication, information is given to the ant about the quality of the path.

ACO acts in the same manner as the ant colonies seeing that the pheromone paths are laid by couples of consecutive cars in order to learn of promising sub-sequences of cars (Salnon, 2008). The paths chosen by the ants are with respect to the probabilities of the paths that were laid down by previous ants (sub-sequences).

Figure 5: Representation of Ant Colony Optimization.

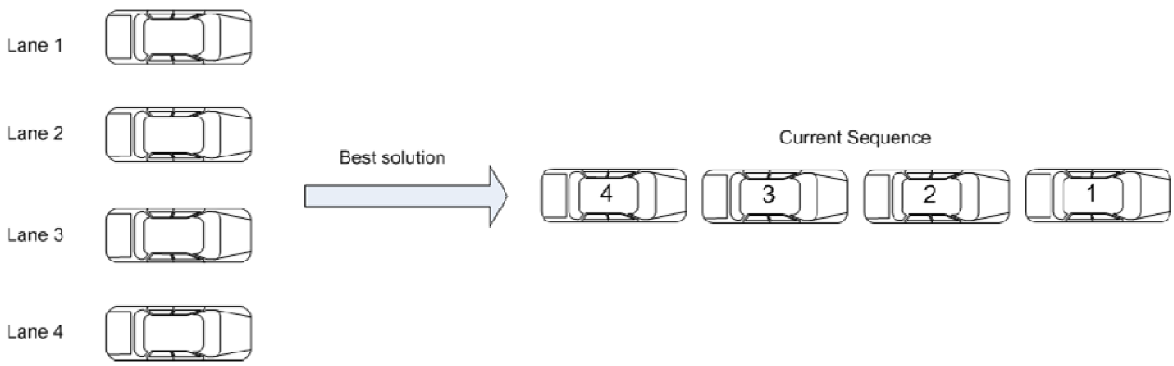


M. Gravel (2005) published a review on Ant colony optimization and stated that the ACO were able to find solutions of quality equal to that of other best known solutions for all of the benchmark problems. He also stated that ACO were able to find these solutions at a rapid rate when compared to the other Integer Linear Programming solutions.

4.3.1.3 Greedy heuristics

The sequence of cars is constructed by evaluating the cars that are not yet placed in the already formed sub-sequence that cannot be modified (Rbeiro, 2008). The evaluation is based on a formulation that will take the next best car and place it in the current partial sequence. The car will never be considered again once the car is inserted to the sequence. This process will be repeated until all cars are placed in the sequence.

Figure 6: Representation of the Greedy Heuristic.



Neighbourhood Greedy Swapping and Shifting – Prandtstetter (2008) mention these methods as a combination of VNS and Greedy heuristics. Neighbourhood Greedy Swapping refers to a restricted set of all possible single swapping moves of a current solution while Neighbourhood Greedy Shifting refers to all solutions obtained by applying a restricted single move to a current solution.

5 Development of Supplementary Methods

In the literature study various types of solutions for the car sequencing problem was identified and discussed. All the methods are applicable to the scheduling of cars at the beginning of the production process. This scheduling considered constraints such as level of resources and paint change over minimization to ensure that the manufacturing process runs as smooth as possible. The main objective of this initial scheduling is to minimize the manufacturing costs taking in consideration the various constraints.

The car sequencing problem at the PBS (Inside the manufacturing process) is somewhat different from the car scheduling and sequencing that takes place in the beginning (Outside of manufacturing process). The cars entering the PBS is out of their initial sequence hence rescheduling and sequencing have to be done in the PBS to ensure that the cars enter the Trim line in the correct sequence.

Application of the methods mentioned in the literature review will assist in the rescheduling and sequencing of the cars in the PBS.

5.1 Improvement at the PBS put in context to the car sequencing problem methods.

5.1.1 Variable Neighbourhood search

Initial Solution – Cars are exiting the Paint shop in a random sequence.

Neighbourhood – Due to the nature of the storage lanes the only transformation possible is the forward moving transformation. This transformation can be done to the storage lane that has the optimal solution.

5.1.2 Ant Colony Optimization

This method will take information of the cars that are already in the storage lanes and calculate the respective sub-sequences. The cars exiting the Paint shop will then choose the storage lane that shows the greatest probability for achieving the optimal sub-sequence.

5.1.3 Greedy Heuristic

The sequence of the cars that are already stored on the storage lanes cannot be changed. The heuristic should evaluate the cars exiting the Paint shop as to what storage lane will be the best solution for those specific cars.

6 Data analysis

6.1 Basic Data

Data are collected by the operator at the X-Paint and Into Trim scanning points. This data consist out of the time and date entering and exiting the PBS at the respective scanning points, the Model Job number, the X-Paint: Sequence and the Into Trim: Sequence.

The data will form part of the algorithms developed in this project as well as the evaluation of these algorithms.

Data to be included in the solution of the car sequencing problem will consist of:

- Douki-Seisan number – Generated at production scheduling. This number is assigned to the vehicle in the sequence that the vehicles will start production.
- Type of Model Trim line - Multi Model Committed Trim line and QW Committed Trim line.
- S.S.A.R. Ratio Ratings - To evaluate the new heuristic.

6.2 PBS Facility

The PBS facility is situated after the Paint Shop and before the Trim lines for the Multi models and QW models. It acts as a storage area for the painted bodies coming out of the paint shop before entering the respective trim lines. Figure 26: PBS Facility Layout illustrates that the PBS Facility has 32 lanes and can accommodate between 8 to 13 vehicles in each lane. It has 4 Stations that's responsible for directing the vehicles inside the PBS facility. These stations are manned by operators that are responsible for the vehicles being scanned when entering and exiting the PBS, vehicles being shuffled between the various lanes and the commitment of vehicles to the trim line.

Due to the great size and numerous lanes the PBS Facility can be a substantial contributor to Nissan in achieving better S.S.A.R. ratings. Opportunities to shuffle vehicles inside the PBS arise on various occasions so that S.S.A.R. ratings can be increased. These occasions occur when the operators have to choose the lanes in which a vehicle is stored. The selection of lane in which the vehicle is stored plays an integral part as vehicles are to overtake other vehicles that have a higher Douki Seisan number when put in the wrong lane.

6.2.1.1 Operations at the PBS Facility

Operators at the various stations inside the PBS Facility are in control of the operations, particular the decisions made at the lanes in which the vehicles are stored. Refer to Figure 7: Flowchart for the AS-IS modelFigure 9: AS-IS model at decision node and Figure 26: PBS Facility Layout, where the operations are explained with the following.

Models come out of the Paint shop on the Ex-Paint line into the PBS facility. When entering the facility the Vin Number sticker is attached to the vehicle by the operator at Station 1. The vehicle then moves to the end of the Ex-Paint line where Station 2 or 3 sort the vehicle as QW Models or a MM Models. The respective models are then submitted to the QW or the MM area. The QW area consists of lanes 1 to 13 whereas the MM area consists of lanes 14 to 28.

Depending on the type of QW model the vehicles are committed to lane 8, 11, 12 and 13 by the operator at Station 2. When committed to lane 8 the vehicles are transported to the end of the lane where the operator at Station 1 decides to place the vehicles in lanes 1 to 7 these vehicles are placed in the lane in respect of the type of model. Lanes 11, 12 and 13 are used when lanes 1 to 8 are occupied, the vehicles are placed here in terms of the type of model. The operator at Station 4 decides which vehicle in lanes 11 to 13 should be placed in lane 10. The vehicles that are committed to the QW Trim line are chosen by the operator at Station 2 from lanes 1 to 7 and lane 10.

The MM vehicles are committed into lanes 14 to 19 by the operator at Station 3. The operator at Station 4 takes the vehicle by model type and commits the vehicle into lanes 20 to 22 with respect of model type. From lanes 20 to 22 the models that must go to the Wax Booth are transported to lane 24 whereas the models that are ready for the MM Trim line are committed by the operator at Station 3. The vehicles that’s done with the operations at the Wax Booth are then placed in lanes 25 to 27 were they are now ready to be committed to the MM Trim line by the operator at Station 3.

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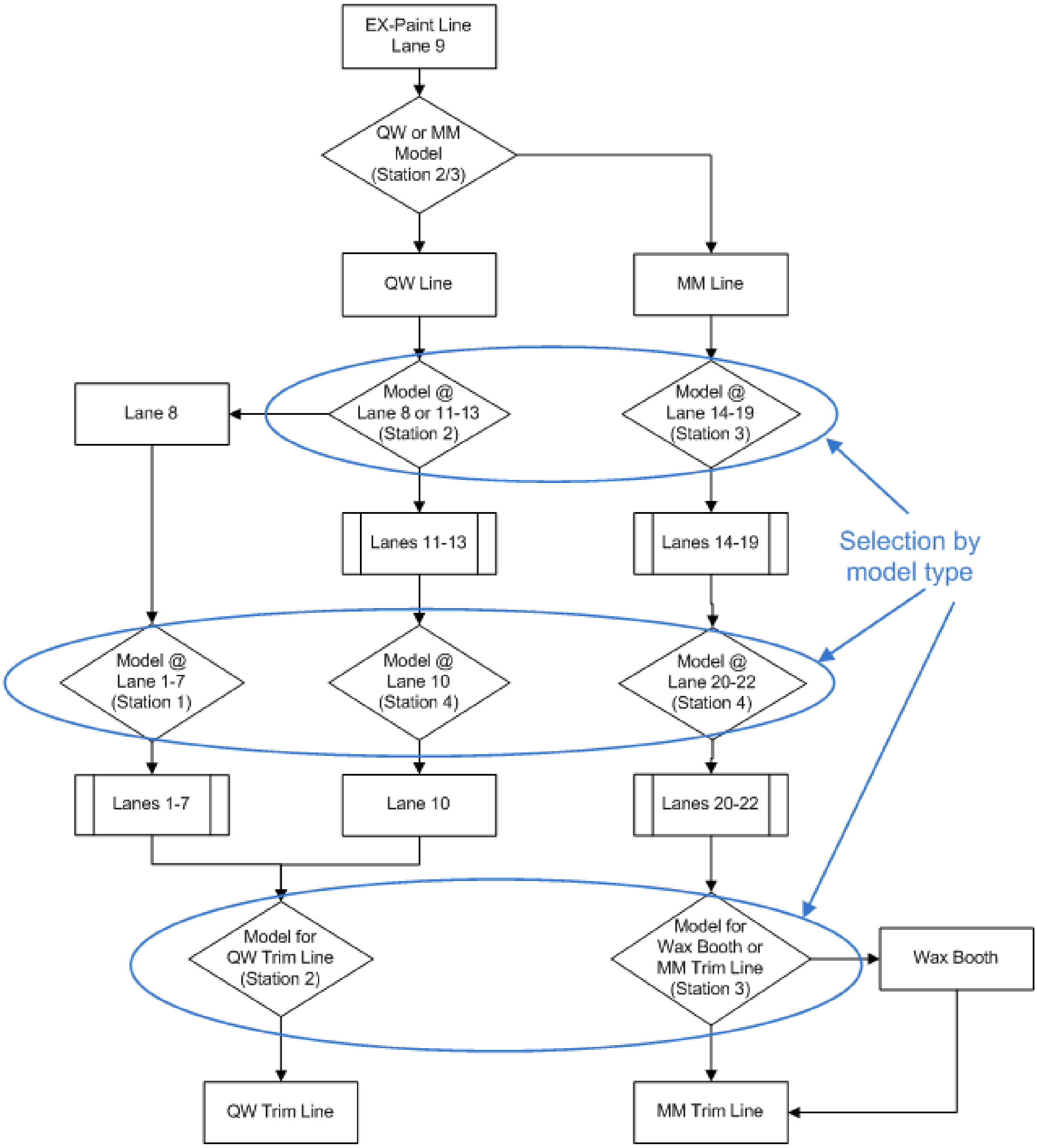
Figure 7: Flowchart for the AS-IS model



6.2.1.2 Restrictions at the PBS facility

Restrictions at the PBS Facilities play a role in the operations at the facility; these restrictions have an influence on the decisions made by the operators cumulating to lower S.S.A.R. ratings.

Lanes 1 to 8 can each be occupied by 8 vehicles whereas lanes 10 to 22 can be occupied by 9 vehicles each. Lanes 1-7, 10, 20-22 and 25-27 moves from the North end of the PBS facility to the South end and lanes 8, 11-19, 24 and 28 moves in the direction of South to North.

Once a vehicle is stored in a lane it can only exit the lane when the vehicle is at the end of the lane. There is no procedure in place for the operators in the facility to take a vehicle that is in the middle of a lane and surrounded by other vehicles out and move it to another lane.

Transfer cars are used to move the vehicles from one lane to the other, this movement is in a bidirectional west to east. The respective transfer cars can only move to the lanes that are allocated to them, e.g. transfer car 1 is allocated to lanes 1 to 11; transfer car 2 is allocated to lanes 8 to 18.

When parts are not available for the Trim line the vehicles are sidetracked or kept in the PBS Facility, this lowers the S.S.A.R. ratings as these vehicles are overtaken by the other vehicles.

The direction in which a lane moves is set; this direction can only be changed by moving the motor of the conveyor to the other end of the lane. This alteration to the lane takes up to a day to complete and the lane cannot be used during this period.

7 Development of conceptual solution

In solving the car sequencing problem at the PBS a combination of the Greedy heuristics and Variable Neighbourhood Search will be used. This method, Neighbourhood Greedy Shifting, consist of all candidate solutions which can be obtained by applying a single shift move to a current solution (Prandtstetter, 2008).

7.1.1 Into the PBS

Greedy Heuristic: The storage lanes in the PBS already have a certain sequence of cars (formed sub-sequence) stored on it. The heuristic then have to decide to which sequence of the available storage lanes the next car will be placed in. This decision will be based on minimizing the difference between the Douki-Seisan numbers of the cars that is last in the respective storage lanes and the car that is committed in to the PBS.

Variable Neighbourhood Search: Forward Shifting will be applied as the car coming from the Paint Shop can only be added to the storage lanes. The nature of the storage lanes will not permit a car to be swapped or k-exchanged.

7.1.2 Exiting the PBS to commit cars to the Trim Line

The same principle will be applied as was the case in entering the PBS.

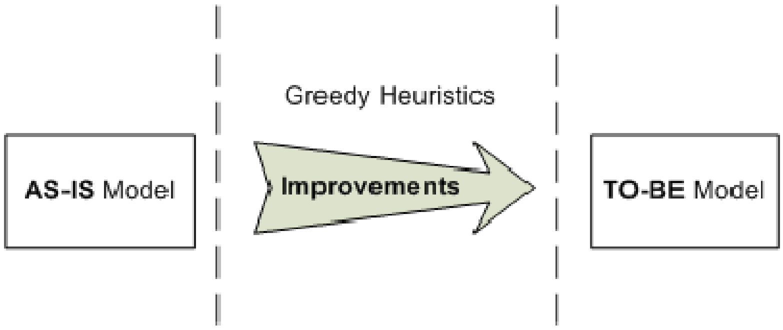
Greedy Heuristic: The commit lane to the Trim Line will act as the formed sequence. The Heuristic will then formulate which car will preeminent the cars in the respective storage lanes. Again the decision will be based on minimizing the difference between the Douki-Seisan numbers.

Variable Neighbourhood Search: To commit the vehicles in the Trim Line, Forward Shifting will again be applied as vehicles in the storage lanes can only be added to the Trim Line.

7.2 Simulation Modelling

Simulation modelling aids a business to see the outcome of a process change before putting it into actual practice (Kellner, 1999). The model will be used to evaluate the results of the changes that have been made to the process. These results will then be evaluated against the current process and adapted where necessary.

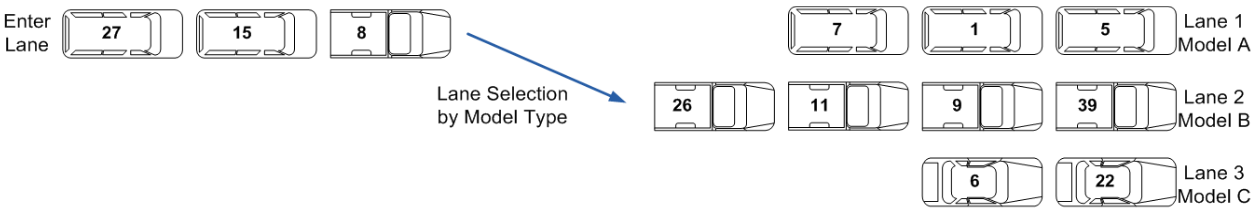
Figure 8: Illustration of Improvement from AS-IS to TO-BE



7.2.1 AS-IS Model

The AS-IS model is a model that shows the state the PBS is currently in without any changes being made to it. This model will aid in determining how well the TO-BE model performs in achieving S.S.A.R. ratings.

Figure 9: AS-IS model at decision node



The decisions that are made to determine the lane to which the vehicle should go are based on the model type e.g. X11J, X11C, N11J, U90 and B90 as illustrated in Figure 9: AS-IS model at decision node.

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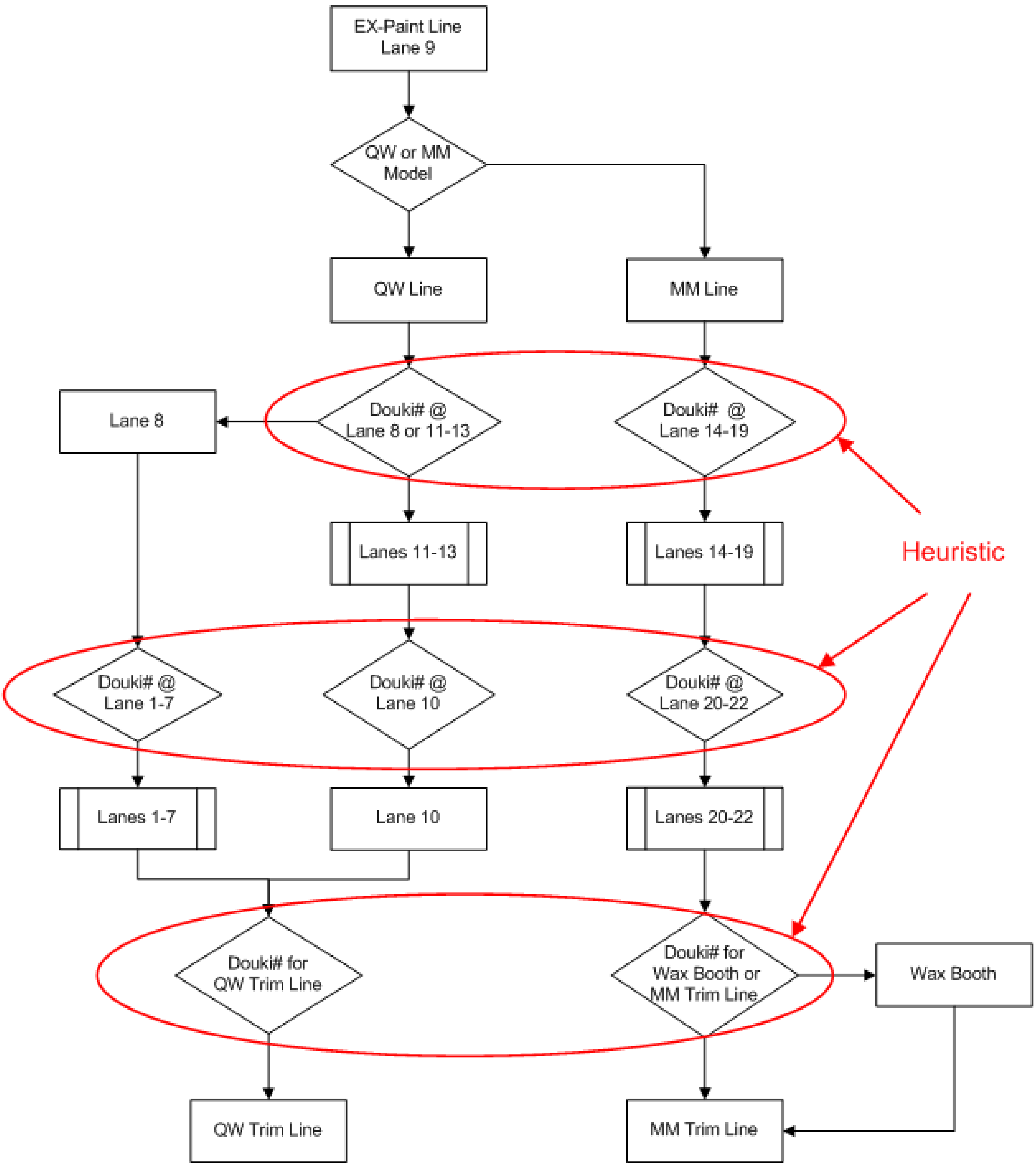
TO-BE Model

The TO-BE model will result from the AS-IS model with improvements being made through applying the Heuristic at the decision nodes in the AS-IS state.

Figure 10: Flowchart for the TO-BE model.



8 Heuristic

The heuristic developed in this chapter will be implemented at the decision nodes in the PBS Facility. This heuristic aims to minimize the difference in Douki Seisan number between the vehicle that needs to be submitted and the vehicles that are in the lanes at the PBS Facility.

8.1 Decision nodes Variable

Various constraints and variables will play a part at the decision nodes of the PBS facility where it will be determined where vehicle *P* will be stored.

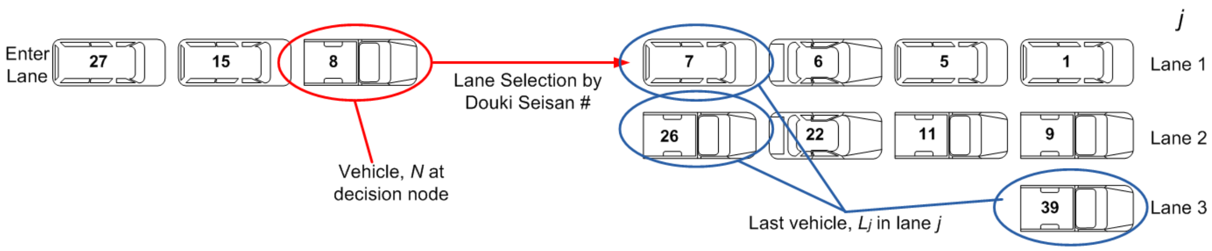
The following Constraints / Variables are defined:

J	=	The number of lanes that are available at a decision node
C_j	=	Capacity of lane *j*: 1 → J
K_j	=	Number of vehicles on lane *j*: 1 → J
S_j	=	Space available on lane *j*: 1 → J
P	=	Douki Seisan number of the vehicle that must be stored
L_j	=	Douki Seisan number of the last vehicles in lane *j*: 1 → J
D_j	=	Difference in Douki Seisan number between vehicle P and vehicle L_j

8.2 Description

When vehicle *P* arrives at the decision node its Douki Seisan number is evaluated in terms of the Douki Seisan number of the vehicle L_j that's the last vehicle in lanes *j*. The Heuristic selects the vehicle L_j in lanes *j* that has the smallest difference in Douki Seisan number in terms of vehicle *P* at the decision node. This selection prefers vehicles L_j in lanes *j* that has a lower Douki Seisan number than vehicle *P*. If all the last vehicles L_j in lanes *j* have a Douki Seisan number that is greater than vehicle *P* the heuristic will select the vehicle which Douki Seisan number is the closest to vehicle *P*. When the Capacity, C_j of the respective lanes *j* is taken no Space, S_j is left and the lane will not be considered in the heuristic. S_j is determined by the difference of the Capacity, C_j of lane *j* and the number of vehicles, K_j that's already on the lane. Vehicle *P* will then be placed after the selected vehicle L_j.

Figure 11: TO-BE model Decision node



8.2.1.1 *Objective*

Minimize the difference D_j in Douki Seisan number between vehicle *P* and the last vehicle in lane *j*.

Min (D_j) for each lane *j*: 1 → J

8.2.1.2 *Heuristic Steps*

1. Evaluate P
2. For all *j*: 1 → J, Compute $S_j = C_j - K_j$
3. For all *j*: 1 → J, Get L_j
4. For each j, Compute $D_j = P - L_j$
5. Determine if there is a positive D_j
6. If there is a positive D_j

   Select D_{min} = Min (Positive D_j)

   else

   Select D_{min} = Min (Negative D_j)
7. Assign P to lane *j* where D_{min} was found

9 Model

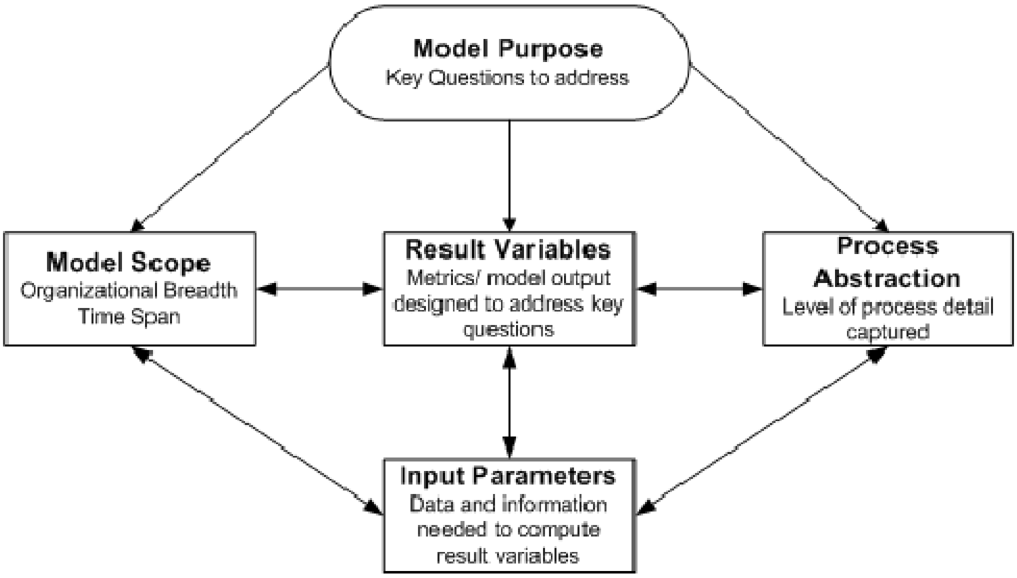
9.1 Model Purpose

The model will assist in recording data and testing the TO-BE model.

9.2 Model Scope

The scope of the model will consist of the whole PBS facility excluding the processes at the Wax Booth. Although the Wax Booth will be considered in the simulation model the process inside the Wax Booth won't be modelled thus it will be modelled as a conveyor.

Figure 12: Relationships among the modeling aspects.



9.3 Result Variables

The Result variables are the information that will be used to evaluate the two models. Typical Results variables that will be used in this model are:

- S.S.A.R. Ratings
- Throughput
- Staff Utilization Rate
- Cycle-time
- Queue lenghts

9.4 Process Abstraction

The process abstraction looks at all the key elements in the process and how they interact with one another. The focus is on the aspects of the process that are especially relevant to the purpose of the model and also influence the result variables (Kellner, 1999).

Key elements that are relevant to this model includes:

- Key activities/ tasks
- Resources
- Feedback loops
- Decision Points

9.5 Input Parameters

To compute results data and information needed will consist of:

- Enter PBS date and time
- Exit PBS date and time
- Enter number
- Exit number
- Douki number

9.6 TO-BE Model

This model is simulated by making use of the basic processes of the As-Is model and implementing the Heuristic at the respective decision points. The decision points are simulated by the use of the PickStation module; this module takes the Heuristic and assigns the vehicle to the determined lane.

The To-Be model is broken up into two simulation models; a Multi Model and a QW Model. A detailed description of the two models follows. Refer to Figure 27: To-Be Model, Multi Model and Figure 28: To-Be Model, QW Model

9.6.1 Multi Model

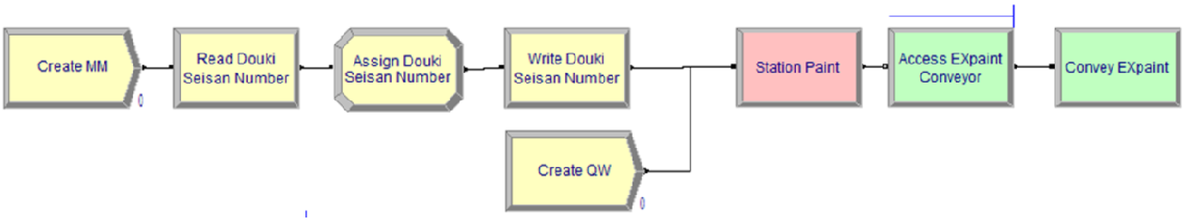
9.6.1.1 Create Multi Model vehicles

The Create module (Figure 13) generates the various vehicles that come from the Paint Shop. These vehicles consist of Multi Models (MM) and QW Models (QW). The arrival time of the MM vehicles depend on an expression “0.999 + 362 * BETA(0.192, 0.635)” that were developed by the input analyser of the Arena Simulation program.

The Create MM module is followed by a Read Write module that reads Douki Seisan Numbers from an Excel file to the simulation model. These Douki Seisan Numbers are then assigned to the entities as attributes by use of the Assign block. A Read Write module writes the Douki Seisan Numbers to an Excel file for later analysis.

The Station Paint module is used to define a logical location for the vehicles to access the EX-Paint conveyor.

Figure 13: MM Model; Create Entities, A

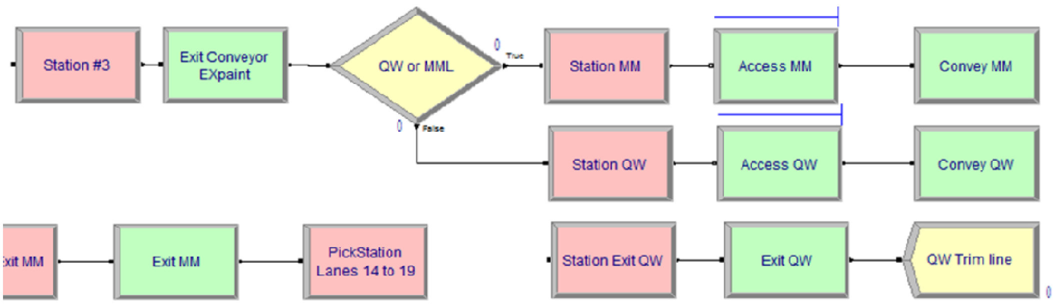


9.6.1.2 QW or Multi Model

At Station #3 (Figure 14), the vehicles exit the Ex-Paint conveyor to the decision module that decides whether the vehicle is a Multi Model or a QW vehicle.

The vehicles enter the QW or MM part of the PBS by accessing the conveyors, Convey QW and Convey MM respectively at stations, Station QW and Station MM.

Figure 14: MM Model; QW or Multi Model, B



9.6.1.3 Decide between lanes 14-19

In the To-Be model a PickStation block (Figure 15), determines the lane that the vehicles should be placed in. The lanes range from lane 14 to 19. The TO-BE model decision is based on the Heuristic that places the vehicles in the lanes by the best solution according to their Douki Seisan Numbers.

Figure 15: MM Model; PickStation lanes 14 to 19, C

9.6.1.4 Multi Model Conveyor

A vehicle access the conveyor (Figure 16), according to the decision that has been made by the PickStation block. All conveyor modules are defined by the following characteristics: Type – Accumulating, Velocity – 0.0001 m/s and Max Cells Occupied – range between 8 and 11. Accumulating refers to the conveyor that is always moving even if loading or unloading creates local blockages on the conveyor.

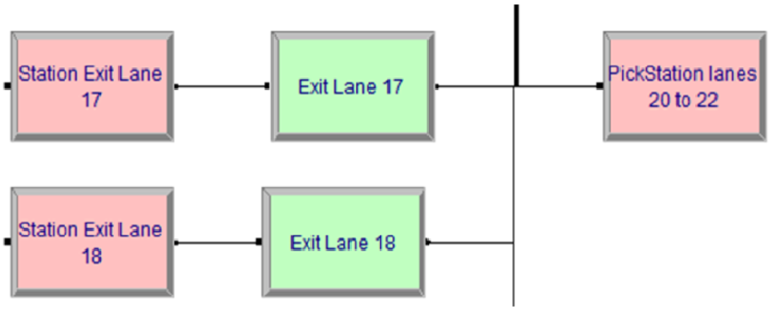
Before a vehicle can exchange conveyors it has to exit by means of the Exit module e.g. Station Exit Lane 17.

Figure 16: MM Model; Conveyor, D

9.6.1.5 Decide between Lane 20-22

This PickStation (Figure 17) module picks the lane, lane 20, 21 or 22, to which the vehicle must be committed to by means of the Heuristic.

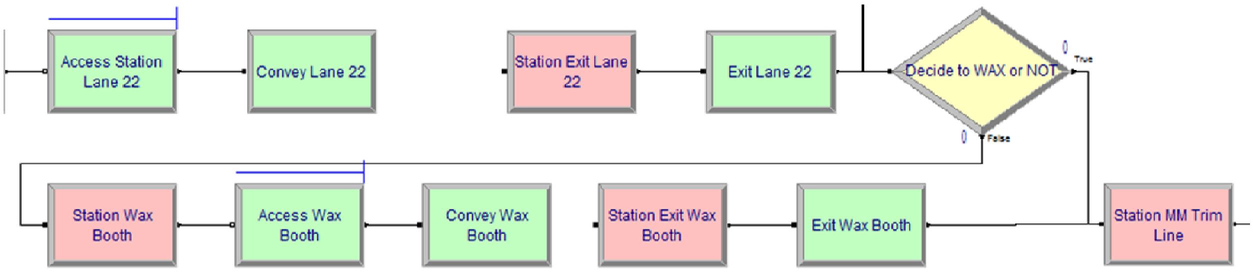
Figure 17: MM Model; PickStation lanes 20,21 and 22, E



9.6.1.6 Waxed cars

The U90 and B90 vehicles are committed to the Wax Booth before they are committed together with the X11C, X11J and N11J models onto the Multi Model trim line. A Decision Block (Figure 18), sorts the models for the Wax Booth.

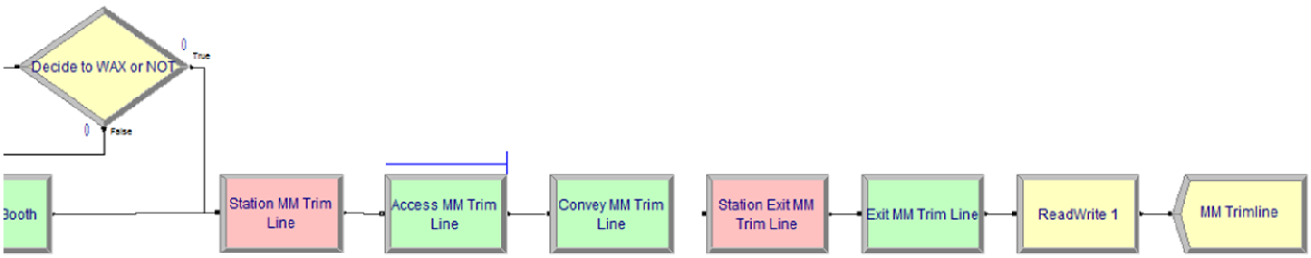
Figure 18: MM Model; Wax or Not, F



9.6.1.7 *Multi Model Trim Line*

Vehicles are chosen by the operator either from the Wax Booth or lanes 20, 21 and 22 to access the Multi Model Trim Line conveyor. Here again the decision is based on the Heuristic that decides the lane that will be drawn to commit a vehicle to the Multi Model Trim Line (Figure 19). The Douki Seisan Number of the vehicle exiting the PBS Facility is recorded by the Read Write module to the Excel file where the Douki Seisan Number is evaluated in terms of its S.S.A.R. rating.

Figure 19: MM Model; Trim Line, G



9.6.2 QW Model

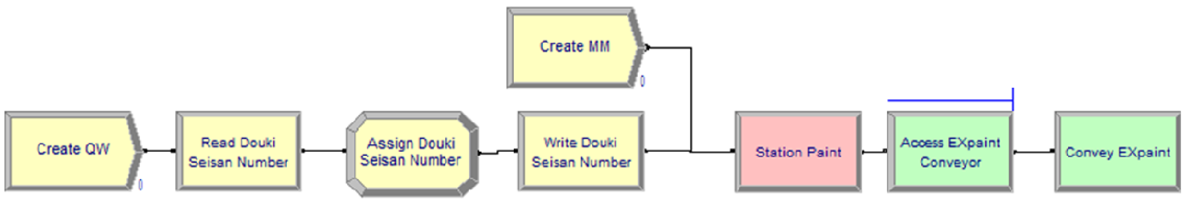
9.6.2.1 Create QW Model vehicles

The Create module (Figure 20) generates the QW vehicles that come from the Paint Shop. The arrival time of the QW vehicles depend on an expression “0.999 + 362 * BETA(0.192, 0.635)” that were also developed by the input analyser of the Arena Simulation program.

Similar to the Multi Models the Create QW module is followed by a Read Write module that reads Douki Seisan Numbers from an Excel file to the simulation model. These Douki Seisan Numbers are then assigned to the entities as attributes by use of the Assign block. A Read Write module writes the Douki Seisan Numbers to an Excel file for later analysis.

The Station Paint module is used to define a logical location for the vehicles to access the EX-Paint conveyor.

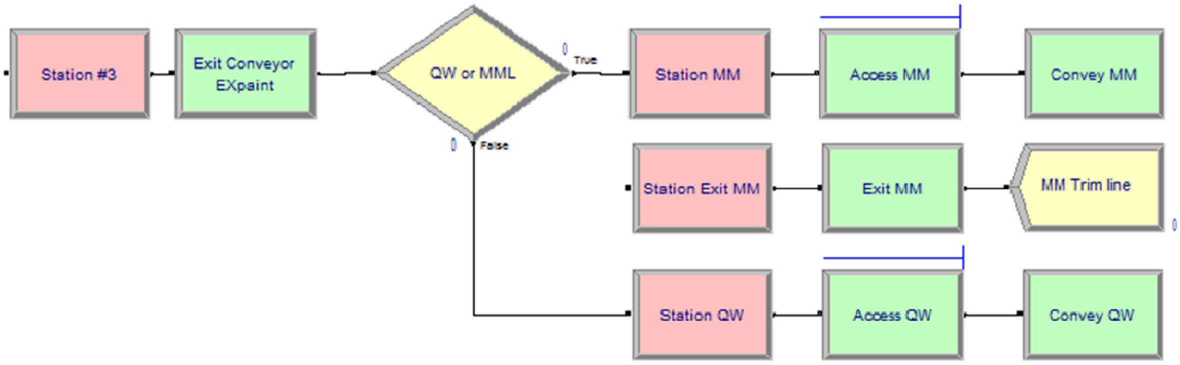
Figure 20: QW Model; Create Entities, A



9.6.2.2 QW or Multi Model

The decision block (Figure 21) determines the type of vehicle and sends the QW models to Station QW to be simulated further in the Model and the Multi Model vehicles are send to Station MM where they are disposed.

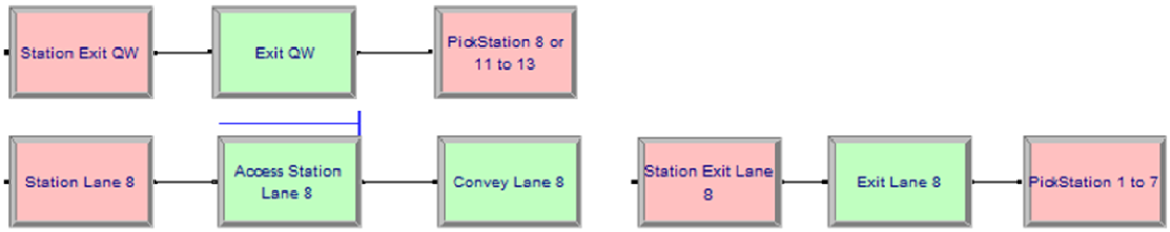
Figure 21: QW Model; Qw or MM Model, B



9.6.2.3 *Decide between Lane s 8 or 11 to 13 and PickStation 1 to 7*

The PickStation 8 or 11 to 13 (Figure 22) uses the Heuristic to commit vehicles to the respective lanes. The vehicles that are committed to lane 8 are then transferred to PickStation 1 to 7 where it also makes use of the Heuristic to determine the lane the vehicle must be committed to.

Figure 22: QW Model; PickStation 8 or 11 to 13 and PickStation 1 to 7, C



9.6.2.4 *QW Model Conveyor*

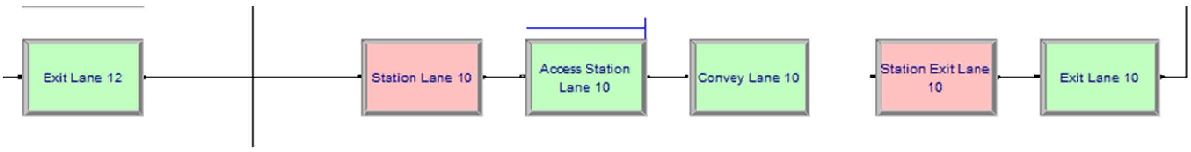
The conveyors (Figure 23) in the QW model have the same characteristics as the conveyors in the MM simulation.

Figure 23: QW Model; Conveyor, D

9.6.2.5 *Return Lane 10*

The vehicles are selected for lane 10 from lanes 11 to 13 with the Heuristic (Figure 24). Lane 10 together with lanes 1 to 7 is used to commit the vehicles to the QW Trim Line.

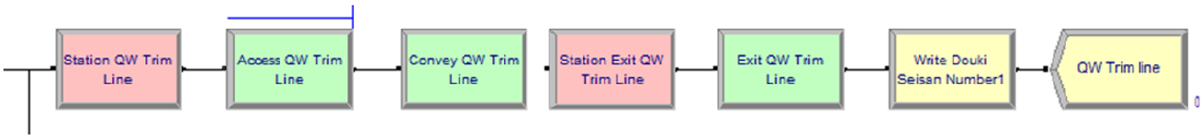
Figure 24: QW Model; Return lane 10, F



9.6.2.6 *QW Model Trim Line*

From lane 10 and lanes 1 to 7 (Figure 25) the vehicles are committed to the QW Trim Line, the selection of vehicles from these lanes is once again done with the Heuristic. The Read Write module writes the Douki Seisan Numbers to an Excel file where the S.S.A.R rating is evaluated. The vehicles are the disposed by the dispose module QW Trim Line.

Figure 25: QW Model; Trim Line, G



10 Results

The TO-BE Model was tested several times with different Douki Seisan Numbers. The Douki Seisan Numbers for the months of November, December and January were used to assign attribute values to the vehicle entities in the TO-BE model. The TO-BE model was executed and data was send to an Excel file were it was evaluated in terms of the S.S.A.R. ratings.

The S.S.A.R. ratings for the respective months used for the AS-IS model were obtained by the SAP database that is in place at Nissan production plant, refer to Figure 29: Multi Model S.S.A.R. Ratings excel spreadsheet. The database continuously collects data of each vehicle throughout the whole production process by means of scanning points at the beginning and end of each process.

The results obtained for the TO-BE model shows that there is a significant increase in the S.S.A.R. rating.

Improvement of S.S.A.R. in the PBS process

Table 4: S.S.A.R. Ratings of the AS-IS model and TO-BE model

Month	*S.S.A.R. Ratings*			
	AS-IS Model		*TO-BE Model*	
	MM Models	*QW Models*	*MM Models*	*QW Models*
November	10.71%	20.52%	18.97%	
December	10.55%	18.85%	20.69%	
January	13.64%	14.61%	20.69%	

11 Conclusion

Throughout the study of this project it became clear that car sequencing problems can become a complex dilemma and have a large influence in the production of vehicles. Nissan integrated the S.S.A.R. ratings into their process to address this dilemma of car sequencing problems.

The operations inside the PBS Facility can be a major contributor to achieving better S.S.A.R. ratings. By changing the method of decision making at these operations from a model type to the Heuristic developed in this study, vehicles are being brought closer to their original sequence in which they have started the production process.

By achieving better S.S.A.R. ratings more accurate planning can be done in terms of the correct parts being delivered at the right time to the right vehicle on the assembly line.

12 References

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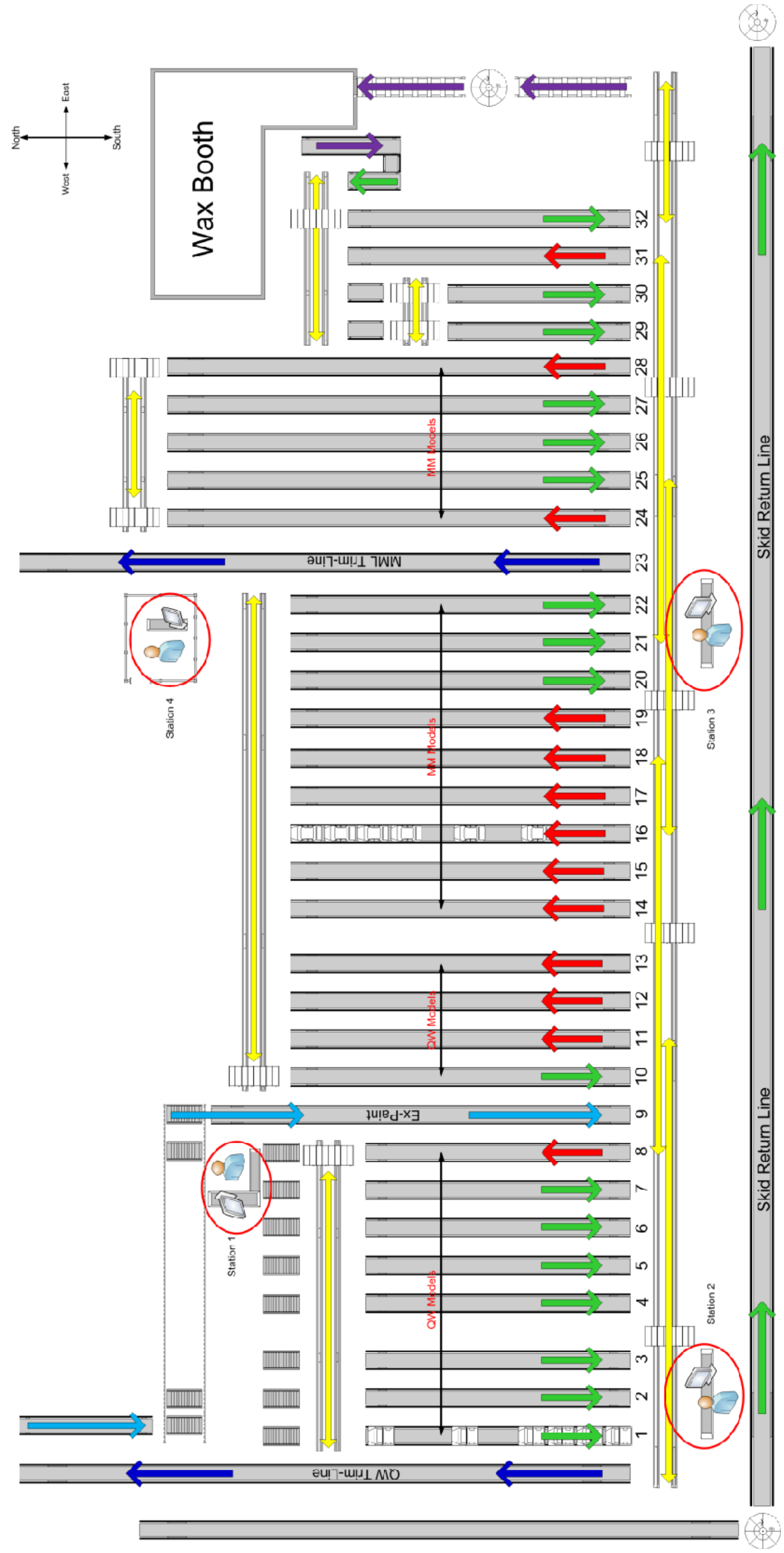
Appendix A

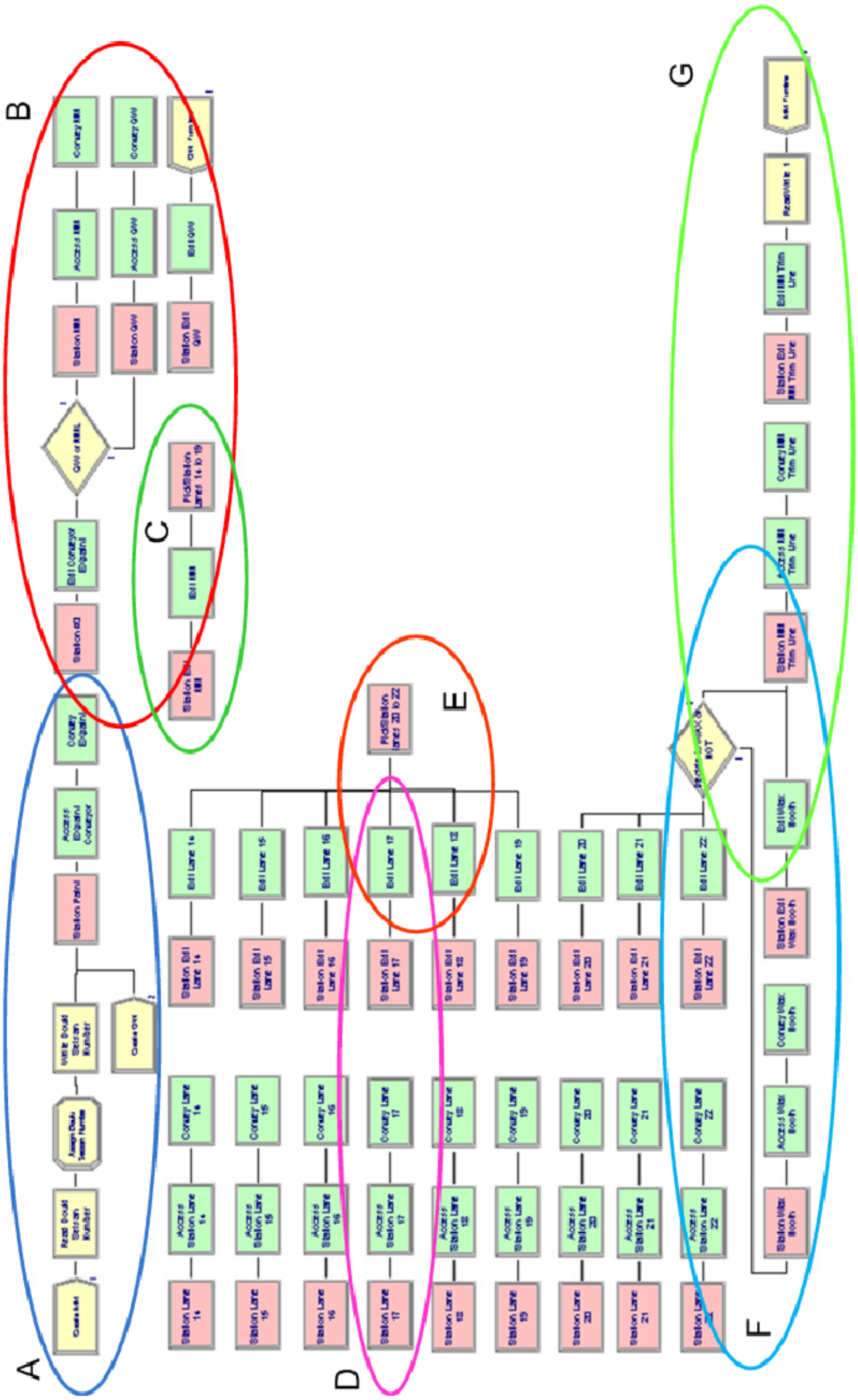
Improvement of S.S.A.R. in the PBS process

Figure 26: PBS Facility Layout



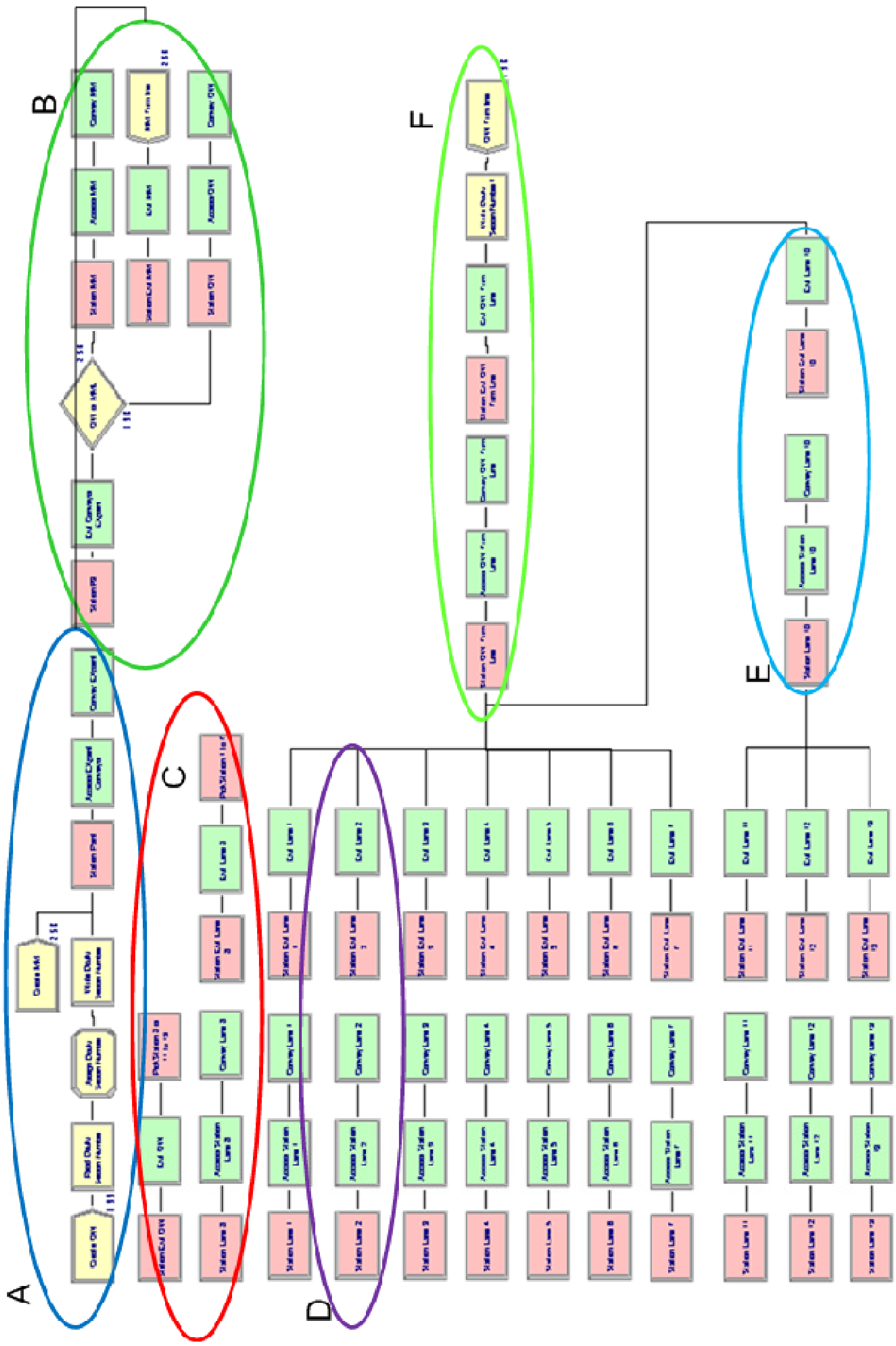
Improvement of S.S.A.R. in the PBS process

Figure 27: To-Be Model, Multi Model



Improvement of S.S.A.R. in the PBS process

Figure 28: To-Be Model, QW Model



Improvement of S.S.A.R. in the PBS process

Figure 29: Multi Model S.S.A.R. Ratings excel spreadsheet

1	LINE1	LINE2	X-Paint:Ext. Time	X-Paint:Model Job no	Into Trim:Ext. Time	Into Trim:Model Job no	Rating	Daily SSAR %	Weekly SSAR %	Monthly SSAR %	X-Paint:Ext. Date	X-Paint:Sequence	Into Trim:Ext. Date	Into Trim:Sequence
2	A004	A005_MML	14:08:00	H350057550	07:37:00	H350057550	OK				10/29/2009	31	11/02/2009	1
3	A004	A005_MML	11:10:00	UA20006051	07:39:00	UA20006051	NG				10/29/2009	18	11/02/2009	2
4	A004	A005_MML	14:10:00	H350057401	07:48:00	H350057401	OK				10/29/2009	32	11/02/2009	3
5	A004	A005_MML	08:04:00	BA50012586	07:49:00	BA50012586	OK				10/30/2009	66	11/02/2009	4
6	A004	A005_MML	11:40:00	H350057475	08:12:00	H350057475	NG				10/29/2009	23	11/02/2009	5
7	A004	A005_MML	07:51:00	BA50012625	08:15:00	BA50012625	NG				10/30/2009	62	11/02/2009	6
8	A004	A005_MML	11:23:00	UA20006536	08:22:00	UA20006536	NG				10/29/2009	19	11/02/2009	7
9	A004	A005_MML	13:44:00	H790013849	08:27:00	H790013849	OK				10/30/2009	95	11/02/2009	8
10	A004	A005_MML	08:37:00	BA20005499	08:29:00	BA20005499	NG				10/30/2009	71	11/02/2009	9
11	A004	A005_MML	08:59:00	H310076099	08:31:00	H310076099	OK				10/31/2009	107	11/02/2009	10
12	A004	A005_MML	11:24:00	UA20005950	08:35:00	UA20005950	NG				10/29/2009	20	11/02/2009	11
13	A004	A005_MML	17:01:00	H350057586	08:40:00	H350057586	NG				10/29/2009	57	11/02/2009	12
14	A004	A005_MML	15:49:00	BA20005500	08:43:00	BA20005500	NG				10/29/2009	41	11/02/2009	13
15	A004	A005_MML	10:41:00	H780006225	08:46:00	H780006225	NG				10/29/2009	17	11/02/2009	14
16	A004	A005_MML	11:35:00	UA20006287	08:49:00	UA20006287	NG				10/29/2009	21	11/02/2009	15
17	A004	A005_MML	08:39:00	H310075849	09:21:00	H310075849	OK				11/02/2009	150	11/02/2009	16
18	A004	A005_MML	16:08:00	BA10003275	09:22:00	BA10003275	NG				10/29/2009	42	11/02/2009	17
19	A004	A005_MML	10:04:00	H790013801	09:27:00	H790013801	NG				10/30/2009	81	11/02/2009	18
20	A004	A005_MML	17:14:00	UA20006300	09:28:00	UA20006300	NG				10/28/2009	8	11/02/2009	19
21	A004	A005_MML	09:25:00	H350057487	09:35:00	H350057487	NG				10/30/2009	74	11/02/2009	20
22	A004	A005_MML	16:16:00	BA50012675	09:39:00	BA50012675	NG				10/29/2009	45	11/02/2009	21
23	A004	A005_MML	11:25:00	H790013851	09:45:00	H790013851	NG				10/31/2009	126	11/02/2009	22
24	A004	A005_MML	10:42:00	H340019986	09:48:00	H340019986	NG				10/30/2009	87	11/02/2009	23
25	A004	A005_MML	08:07:00	UA20006348	09:50:00	UA20006348	NG				10/29/2009	9	11/02/2009	24
26	A004	A005_MML	10:40:00	H350057451	10:02:00	H350057451	NG				10/29/2009	16	11/02/2009	25
27	A004	A005_MML	16:19:00	BA20005386	10:06:00	BA20005386	NG				10/29/2009	47	11/02/2009	26
28	A004	A005_MML	11:24:00	H790013863	10:12:00	H790013863	NG				10/31/2009	125	11/02/2009	27
29	A004	A005_MML	08:24:00	UA20006198	10:13:00	UA20006198	NG				10/29/2009	10	11/02/2009	28
30	A004	A005_MML	10:40:00	H350057562	10:18:00	H350057562	NG				10/30/2009	85	11/02/2009	29
31	A004	A005_MML	10:48:00	BA70005912	10:20:00	BA70005912	NG				10/30/2009	91	11/02/2009	30

Improvement of S.S.A.R. in the PBS process

Figure 30: QW Model S.S.A.R. Ratings excel spreadsheet

1	LINE1	LINE2	X-Paint:Ext. Time	X-Paint:Model Job no	Into Trim:Ext. Time	Into Trim:Model Job no	Rating	Daily SSAR %	Weekly SSAR %	Monthly SSAR %	X-Paint:Ext. Date	X-Paint:Sequence	Into Trim:Ext. Date	Into Trim:Sequence
3839	A004	A005_QW	09:21:00	K080038813	13:18:00	K080038813	NG				11/27/2009	1,848	11/30/2009	1,914
3840	A004	A005_QW	08:05:00	K150007762	13:23:00	K150007762	NG				11/30/2009	1,921	11/30/2009	1,915
3841	A004	A005_QW	09:56:00	K080038801	13:25:00	K080038801	NG				11/27/2009	1,854	11/30/2009	1,916
3842	A004	A005_QW	08:47:00	K080038900	13:27:00	K080038900	NG				11/30/2009	1,935	11/30/2009	1,917
3843	A004	A005_QW	09:35:00	K150007801	13:29:00	K150007801	NG				11/30/2009	1,937	11/30/2009	1,918
3844	A004	A005_QW	09:04:00	K080038912	13:36:00	K080038912	NG				11/30/2009	1,936	11/30/2009	1,919
3845	A004	A005_QW	10:50:00	K090005750	13:38:00	K090005750	NG				11/27/2009	1,859	11/30/2009	1,920
3846	A004	A005_QW	13:11:00	X860000487	13:41:00	X860000487	OK				11/30/2009	1,940	11/30/2009	1,921
3847	A004	A005_QW	11:26:00	K050003150	13:43:00	K050003150	NG				11/27/2009	1,866	11/30/2009	1,922
3848	A004	A005_QW	08:34:00	K080038875	13:51:00	K080038875	NG				11/30/2009	1,931	11/30/2009	1,923
3849	A004	A005_QW	08:03:00	K150007774	13:57:00	K150007774	NG				11/30/2009	1,920	11/30/2009	1,924
3850	A004	A005_QW	07:57:00	K080038748	14:01:00	K080038748	NG				11/27/2009	1,839	11/30/2009	1,925
3851	A004	A005_QW	08:43:00	K080038936	14:05:00	K080038936	NG				11/30/2009	1,933	11/30/2009	1,926
3852	A004	A005_QW	11:00:00	K150007851	14:17:00	K150007851	NG				11/30/2009	1,938	11/30/2009	1,927
3853	A004	A005_QW	13:48:00	X560000336	14:20:00	X560000336	OK				11/30/2009	1,942	11/30/2009	1,928
3854	A004	A005_QW	11:49:00	K100008099	14:24:00	K100008099	NG				11/27/2009	1,871	11/30/2009	1,929
3855	A004	A005_QW	14:01:00	X970000536	14:34:00	X970000536	OK				11/30/2009	1,943	11/30/2009	1,930
3856	A004	A005_QW	14:47:00	K090005798	14:37:00	K090005798	NG				11/27/2009	1,900	11/30/2009	1,931
3857	A004	A005_QW	08:01:00	K150007837	14:40:00	K150007837	NG				11/30/2009	1,919	11/30/2009	1,932
3858	A004	A005_QW	10:24:00	K090005712	14:42:00	K090005712	NG				11/27/2009	1,856	11/30/2009	1,933
3859	A004	A005_QW	11:17:00	K080038849	14:46:00	K080038849	NG				11/27/2009	1,862	11/30/2009	1,934
3860	A004	A005_QW	08:11:00	K150007825	14:56:00	K150007825	NG				11/30/2009	1,922	11/30/2009	1,935
3861	A004	A005_QW	08:18:00	K080038887	14:58:00	K080038887	NG				11/30/2009	1,926	11/30/2009	1,936
3862	A004	A005_QW	11:25:00	K090005724	15:00:00	K090005724	NG				11/27/2009	1,865	11/30/2009	1,937
3863	A004	A005_QW	14:43:00	X980000598	15:10:00	X980000598	OK				11/30/2009	1,944	11/30/2009	1,938
3864	A004	A005_QW	11:46:00	K090005825	15:12:00	K090005825	NG				11/27/2009	1,870	11/30/2009	1,939
3865	A004	A005_QW	08:46:00	K080038948	15:14:00	K080038948	NG				11/30/2009	1,934	11/30/2009	1,940
3866	A004	A005_QW	15:23:00	K110006986	15:17:00	K110006986	NG				11/27/2009	1,905	11/30/2009	1,941
3867	A004	A005_QW	11:58:00	K090005849	15:18:00	K090005849	NG				11/27/2009	1,873	11/30/2009	1,942
3868	A004	A005_QW	13:27:00	X860000499	15:20:00	X860000499	NG				11/30/2009	1,941	11/30/2009	1,943
3869	A004	A005_QW	13:38:00	K090005837	15:24:00	K090005837	NG	14.61	14.61	20.52	11/27/2009	1,892	11/30/2009	1,944

s