Optimizing the RG31 production line at British Aerospace Land Systems SA

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GLOSSARY

Term	Abbreviation	Definition
Just-in-Time	JIT	When component parts arrive at a production line just moments before they are used on the production line.(Trained, 1996)
Kaizen	Kaizen	Continuous Improvement of processes and procedures throughout an organization. (Liker, 2006)
Kanban system	Kanban	"Cards instructing the production line to make a certain quantity of a certain end product." (Liker, 2004)
Supply chain network	SCN	Network in which customers, suppliers, logistics providers, carriers, and financial institutions are all connected. (Lidow, 2002)

EXECUTIVE SUMMARY:

The expansion of a plant can lead to many difficulties. This had been the case at BAE Land Systems SA. The company is a division of BAE Land Systems and is experiencing rapid expansion due to large contracts received. More production lines need to be established, more vehicles need to be built in the same time as in the past, more staff needs to be contracted and more systems need to be implemented. This project will focus on exploiting problems in the production line and the supply system of the consumables that are needed on the production line in order to achieve the needed expansion in production.

Using a top-bottom approach helped to identify the need to produce more vehicles per day. Two big problems stand out. Firstly, that the production line should be fitted to a schedule and, secondly, that the production line encounters production standstills because of insufficient supplies at stations, thus resulting in a slow production ratio.

These problems are addressed separately, but with established communication between the two production systems. The production line is placed on an hourly schedule to ensure constant output. To achieve this, production is balanced between the production line stations. In addition, bottle necks at station six are fixed by way of redesigning the tools which are used at the assembling points of valves. The supply chain has been redesigned with the help of tuggers and trolleys, which ensure that the supplies arrives just-in-time to eliminate the problem of production standstills. In addition, the inventory on the line has been reduced.

It is critically important to run the production line as smooth as possible and to keep the production rate high, in order that the production demands are met and that BAE can continue to grow its business.

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1. INTRODUCTION AND BACKGROUND

BAE Systems Land Systems is an international company which is situated in Great Britain and which designs and manufactures military systems. These systems are anything from combat- and anti-ambush vehicles to aircrafts, fighter planes, submarines, tanks and large aircraft carriers. The company has over the past few years expanded into other countries and established production plants all over the world.

BAE Land Systems SA, the South African division, is situated in Benoni and is a division of BAE land Systems South Africa. It specializes in the design and manufacture of ground vehicles, including tanks and mine protective vehicles for local and international customers. The company does not just manufacture these products but is also responsible for maintenance, refurbishment and customer support.

The production line consists of 13 assembly stations and 3 sub-assembly stations. Each station has between 3-6 employees who are responsible for installing parts and working on the line. Vehicle bodies enter at station 1 on a trolley where more armor is added. Twelve stations later, the vehicle is ready to leave the production on its own after a battery has been inserted at the 13th station. The focus of this project is to exploit the non-productive areas in the production line and to ensure the timely supply of necessary parts and consumables at each of the 13 production stations. The successful implementation of a new supply system on the production line should lead to the new system being duplicated to all other existing productions lines.

For BAE Land Systems SA to complete and successfully manage the rapid expansion, they need to look at the efficiency of a new supply system. The project will include Industrial Engineering techniques such as Supply Chain Management, time studies and the implementation of JIT and a Kanban system which would help the cause of this project. Briefly explaining the principles mentioned above will have the following benefits for the company:

- **JIT** will ensure that the trolleys carrying the supplies and consumables will only be on the production line when the supplies are needed to complete the production process. This will reduce unnecessary parts and supplies on the production floor and will lead to the 5S principle that states that everything is on its place and tidy.(Trained, 1996)
- The **Kanban** system is a system that sends a signal to the supply staff that alerts them that there is a low level of a certain part or consumable and that stock are close to depletion. The product can then be replaced without delays in the production line. This cycle is repeated. (Liker, 2004)

The Implementation of this system will be weighted against the existing system on the production line.

2. PROJECT AIM

The project aims to design a new production and supply system, which should ensure higher levels of productivity. The production system is divided into two sub-systems, namely the production line and the supply chain. The production line functions according to a schedule so that it can provide a constant output of vehicles. The supply chain aims to function according to the production schedule and to supply materials and consumables on time by means of tuggers and trolleys. The tuggers will replace the empty trolleys at the work stations on the production line. The aim is to find the best route for the tugger and the intervals at which a tugger has to be sent to replace a trolley. The project will also look at the Supply Chain Management, the level of supplies on the trolleys and to determine how many vehicle parts are needed on each trolley, and any other techniques that can be implemented to insure a higher production rate. A time study would be needed to obtain information about the existing system in order to improve the system and to implement new production scheduling. The project will also obtain information relating to the time each station takes to finish the job.

The following problems should be addressed and improved:

- Eliminate the wastage of time by having the supplies ready at hand on the production line.
- Lower the chances of the production line standing still.
- Reducing inventory on the production line.
- Improving material flow on the production line.
- Determine the frequency of sending Tuggers with supplies to the production line to keep continuous provision of supplies.
- Reduce the number of idling workers at a certain time.
- Ensuring a higher production rate.

3. PROBLEM ANALYSIS

The company works on a Make-to-Order approach and for that reason works on a very tight schedule with deadlines and demands. Supplying the production line with parts and consumables is an integral part of the company's responsibilities and can be seen as a "do or die" system.

BAE Land Systems SA supplied 121 vehicles to the Spanish military at the end of 2008. The contract was renewed and this time included the supply of 300 more vehicles. Spain received the vehicles on time. However, to finish the production on time, BAE Land Systems SA had to build 5 vehicles every day for 6 weeks. After 3 weeks only 37 cars had been finished and BAE had to stay open and pay the workers overtime for the next 3 weeks because of the excessive work that they had to do to meet their deadline. Several times the whole production line had to be interrupted because supplies and consumables were not immediately available at the required station on the production lines.

The production costs could have been reduced and less pressure could have been placed on the production process, had the production lines been adjusted. Firstly, the current production line needs to be analyzed so that the problem areas can be exploited. Time studies would be the obvious choice of technique in which these two can be evaluated and weighed against each other.

The company suggested a tugger and trolley system to help with the materials handling on the plant. The system would involve a loading bay where the trolleys are loaded with supplies and the transported, by means of a tugger, to the production line. A Kanban system is also suggested. This is a system where a card is lifted to signal low supply levels on the production line.

3.1. Decisive factors for the Tugger and Trolley System

Certain results have to be reached in order for the proposed system to be implemented. Higher levels of efficiency and better handling and provision of materials (parts) must be proven. To reach these conclusions, several calculations and variables should firstly be determined. The level of supplies and consumables that should be placed on the trolleys will have to be determined. It must be of a satisfactory level to meet the demand of the mechanics who work on the line. Supplies must always be available and sufficient but inventory on the line needs to be kept as low as possible.

The supply levels need to be integrated with the frequency at which the tuggers will replace the supply trolleys. The number of tuggers and trolleys will have to be determined, while keeping the cost in consideration.

The dimensions of the tuggers and trolleys also need to be taken into consideration for driving inside the plant, as well as the power of the tugger and the capability of pulling a large amount of trolleys.

4. SOLUTION REQUIRMENTS

The desired objectives of the project should be as follows:

- Implementing a faster way of providing the supplies to the production line by using tuggers.
- Determining the optimal amount of tuggers and the frequency that they must be sent to the production line.
- Determining the optimal level of supplies and consumables on the trolleys.
- Minimizing the chances of a total production line stoppage.
- Generate better material flow by constructing a better layout that is integrated with the tugger system.
- The introduction of the Just-In-Sequence system will lead to the more effective management of supplies and reducing the line inventory.
- Change the production line from a push system to a pull system.
- Improved Materials Handling department.
- Pinpoint continuous improvement opportunities.
- Improved visibility of material shortages.
- Continuous Improvement of processes and procedures throughout an organization.(Liker, 2006)

5. LITERATURE STUDY

5.1. Aim of the study

The aim of this literature study is to determine how other companies have implemented similar solutions and what approach they have utilized. It must then also be determined whether the approach is applicable to our problem. It will give us an idea if the present company practice is suitable to the nature of the company.

5.2. Introduction

The success of the company relies on the integration of the supply chain with the production line. The one can not function properly without the other also functioning properly. For example: if the production line is productive and it functions properly, but there are no supplies at hand for the production line workers to assemble, this will lead to the production line to a stand still.

The literature study will look at the current practice of BAE Systems SA to determine what type of trade is performed, this is followed by a background of automotive production and how this evolved during the past century. The literature study will also investigate the supply chain and the production line, conclude what their respective functions are and what problems could be associated with each of them (bottlenecks, supply chain management and materials handling). A possible solution to the above mentioned problems will be briefly discussed in the form of a systems engineering approach.

Content of the literature study

- Current practice
- Historical review
- Case study
- Bottlenecks
- Supply chain management
- Materials handling
- Systems engineering approach

5.3. Current practice

The company's current practice is still very simple and is based on job-shop approach which is to manufacture a product to the specifications of the consumer. Production based on a job-shop approach is very time consuming and specialized. This is different to what is being described in an article by Joseph Adams, "The shifting bottleneck procedure for job shop scheduling". This as that his problem was that machines did the manufacturing and they needed to minimize some functions on the completion time of the jobs. (Adams, 1988)

In BAE's case, it is a lot easier because the approach utilized by the workers to optimize the production line is different. The quantity of vehicles that BAE must build in their time constraint and to stay competitive in their field, gives them the opportunity to shift from the idea of "job shop" producers to a true assembly line production system.

According Lawrence Burns and Carlos Daganzo, assembly line work stations receive the same fixed job sequence and are coupled together so that there is no work-in-process storage, but are balanced so that jobs move continuously between the stations at a constant rate. They also state that automobile assembly lines usually have these characteristics. (Burns, Daganzo, 1987)
The reason why BAE work stations do not have these characteristics mentioned above, is because of the requirements from the customer that never escalated to such a scale that an assembly line was necessary.

5.4. Historical review

Ben Dankbaar wrote that “Fordism” had been in existence since the 1970’s. The term is derived from the way in which Henry Ford started expanding in the production of cars to mass production. This way of production involved, among other things, a continuously moving assembly line and a highly mechanized production of standardized parts. (Hounshell, 1984)

A Volvo factory in Uddevalla in Sweden eliminated the assembly line approach used by Henry Ford and introduced a complete car assembly by small groups of workers. Researchers described the plant as a step backward in history, back to the traditions of craft production. (Ellegard, Engstrom, Nilsson, 1993)

A step back to traditions of craft production is in my opinion back to the “job shop” approach. It is a step back for a product that needs to be produced on a large scale.

Ford’s principles were applied throughout the world, especially in the post-war construction of the automobile industry. In Japan the industry evolved and developed its own structures and rules that were at that time a product of the circumstances Japan found it under. This production system is still found in its advance form at Toyota, which forms part of the third phase in the car manufacturing evolution called “lean manufacturing”. (Womack, Jones, Roos, 1990) This model of manufacturing is called the Toyota model.

In a paper by Ben Dankbaar, he argues that lean production combines the advantages of craft and mass production, while circumventing the disadvantages of high cost of the craft production and the stringency of mass production. (Dankbaar, 1997)

Lean manufacturing makes best possible use of the skills of the workers, by giving them more than one task, by integrating direct and indirect work, and by encouraging continuous improvement activities (Kaizen). (LIKER, 2006)

5.5. Case study

Let us look at a case study based on an Australian car manufacturer that tried to implement principles of JIT manufacturing. The problems arrived once they tried to improve the manufacturing of their dash assembly line. The assembly line consisted of four main sub-assembly lines and could be seen as a SCN I type manufacturing category because of its main characteristics. (Chan, Smith, 1993)

The problem was simple: they tried to implement these JIT principles to design and evaluate a complex manufacturing process prior to installation. They decided to use a simulation model because of its capability to evaluate the effectiveness of modifications made in the model without any cost implications. (Chan, Smith, 1993)

What they missed was the fact that JIT manufacturing only focused on the production part and not on the production part integrated with the supply chain management. The one can not work without the other. They tried a number of techniques and it cost them a considerate amount of money. It was then decided to use a simulation to help them keep the cost of finding a solution as low as possible.

5.6. Bottleneck

It is very important to identify the areas that impede the production throughput of a facility in order that changes can be made to the system structure to allow products and materials to flow freely through the system.

Oshawa#2 plant is one of two car assembly plants. They felt that it was important to find the source of the bottleneck in the plant and decided to use a monitoring system called "edge". The data captured and displayed by this monitoring system included information such as cycle times, station fault times and production counts. (Braiden, Morrison, 1996)

The monitoring system is an electronic devise that does the same as a human performing time studies and observations on a production line. Thus, time studies and observations can also successfully find bottlenecks in production lines.

5.7. Supply Chain management

A supply chain can be described as a network of facilities that procures raw materials, transforms them into intermediate sub-assemblies and final products and then delivers the products to customers through a distribution system (Billington, 1994).

The most common problems involved in this regard are the coordination of material inventories, the production capacity and availability of supplies, so that the manufacturing of products will satisfy the demand with a high level of uncertainty. (SHAW, 1998)

Firstly, let us identify the type of supply chain network. Lin (Lin, 1996) identifies three main types of Supply Chain Networks (SCN), which are tabulated in Table 1.

Attributes	**Type I SCN**	**Type II SCN**	**Type III SCN**
Manufacturing process	Convergent Assembly	Divergent Assembly	Divergent Differentiation
Primary business objectives	Lean production	Customization	Responsiveness
Product differentiation	Early	Late	Late
Range of product variations	Small	Medium	Large
Assembly process	Concentrating at the manufacturing stage	Distributed to the distribution stage	Concentrating at the manufacturing stage
Product life cycle	Years	Months to years	Weeks to months
Main inventory type	End products	Semi-products	Raw materials
Example industries	Automobile and aerospace	Appliance, electronics and computers	Apparel/fashion

Table 1: *The Properties of Type I, II, and III SCN's. (Lin, 1996)*

It is clear that the nature of the company falls in the Type I SCN category, which is distinguished by the manufacturing process that is convergent and that the focus is on the manufacturing stage.

Supply chain management objectives:

- Enhancing Customer Service
- Expanding Sales Revenue
- Reducing Inventory Cost
- Reducing Transportation Cost
- Reducing Warehouse Cost
- Improving On-Time Delivery
- Reducing Order to Delivery Cycle Time
- Reducing Lead Time
- Reducing / Rationalize Supplier Base
- Expanding Width / Depth of Distribution

This project will only look at the manufacturing part of the supply chain. That means that it will only include the materials handling from the warehouse to the production line.

5.8. Materials handling

New production planning policies integrated with routing policies can be adopted to minimize production costs, while also improving customer quality factors. Although a critical chain link between production and transport sub-systems is the picking process, relatively little changes in the warehousing operations have been properly justified during the last years. (Buil, Piera, 2007)

Roman Buil said that no production plant could be the same as another production plant because of the layout of the structure, the layout of each production line and where the warehouse was situated. (Buil, Piera, 2007)

The company suggested using tuggers to pull trolleys, which are loaded with parts and consumables, from the warehouse to the production line. This suggestion will be incorporated in the new production planning policies and will be integrated with routing policies and with the plant design to minimize production costs. Below is an example of a tugger and trolley.

Wesley Industrial Trailers

Wesley Industrial Trailers deliver maximum maneuverability for forklift-free material handling. Ranging from light to heavy-duty, Wesley Industrial Trailers easily move up to 13,300 lbs. In addition to standard models, Wesley International designs and builds engineered-to-order units to meet the specific material handling application and facility needs of the client.

Trolley candidate:

Features:

- Four-wheel steering
- Tight turning radius.
- Steel construction
- Solid black rubber wheels mounted on aluminum cast
- Diamond plate steel floor
- Spring-loaded pin hook
- Solid non-marking pneumatic tires on aluminum cast
- Expanded metal floor
- “1/2" plywood floor
- Cast iron pintle hook.

5.9. Systems Engineering Approach

Systems engineering is an interdisciplinary approach and provides the tradeoff analyses and integration between system elements to achieve the best overall product or service. (Lalk, 2003)

A system is a complex set of various and often-diverse parts subjected to a common plan or serving a common purpose. A System is something that provides a solution to a complex problem. (Lalk, 2003)

Top-down approach

Step 1-With this approach system engineering starts by addressing the complex system as a whole, which facilitates the requirements as well as the subsequent analysis of the system.

Step 2- Brake system down into sub-systems.

Step 3- Brake sub-systems down into its components until a complete understanding is achieved of the system.

By breaking down the system from top to bottom, the interaction between the components can be understood more thoroughly. (Lalk, 2003)

The systems engineering approach is also a linear process. Perhaps the best example is the "Vee Model" as depicted in Figure 1 and described in detail by Forsberg, Mooz and Cotterham.

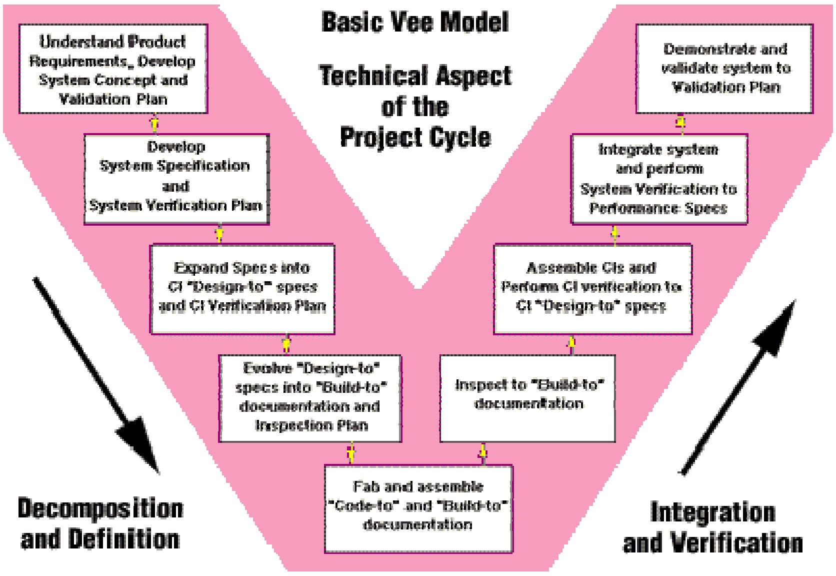


Figure 1: The "Vee" Model (Mooz, Forsberg, Cotterham, 1996)

6. CONCEPTUAL DESIGN

6.1. Project Approach

The project approach strategy below will be used to determine the optimal production line system for BAE Land Systems SA.

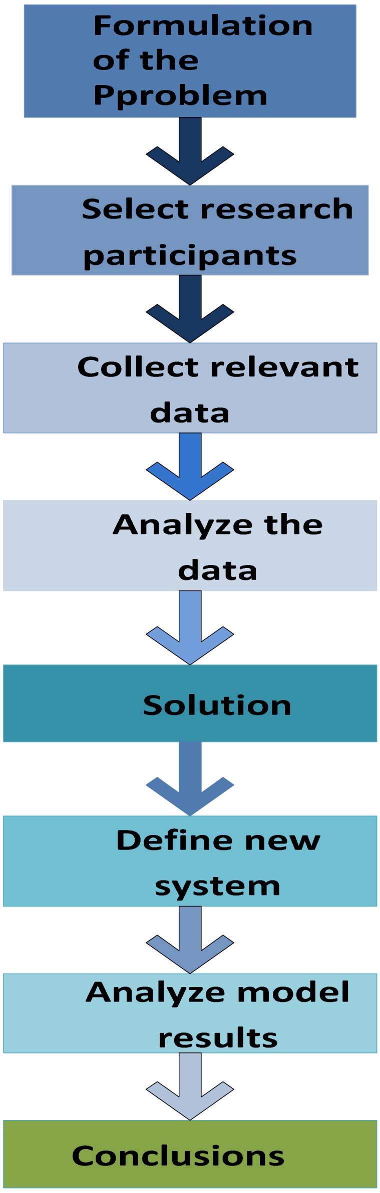


Figure 2: Project approach

6.1.1. Analyzing of the problem

The purpose of the redesigning of the system is to optimize the production line and to prevent production standstills. This will increase production per day and lead to meeting their customer deadlines and to ensure more business. There are many factors contributing to the slow progression of the production line. These factors are as follows:

- The production line shifts irregularly
- The workers shift the vehicles only when they are finished with their jobs on the vehicles. "Job-shop approach"
- Some jobs take longer than others and that lead to a lot of idle workers
- Bottlenecks occur regularly in the production line
- Supplies are not always on hand at required times
- Workplace very cramped because of high supply levels on production line

The data and information gathered should correspond with the above mentioned factors and determine the variables to be used to redesign the production system in the light of the literature review.

6.1.2. Select strategy based on research

From the literature study it is clear that the system needs *redesigning* and that there is an opportunity to change the approach of BAE and to redesign the system from a top-bottom approach. It will be necessary to design the new system from a holistic view point and to break it down into its sub-systems and the subsystems into its various components. The *implementation* of this system would best work with a bottom-up approach. Implementing the components first and building it up to the subsystems and so completing the system.

The literature study has also shown that the "job-shop" approach is affiliated to the craft production approach, which is to manufacture a product to the specifications of a customer and building it at one station. The product on hand at BAE Systems is specialized and is handmade to satisfy customer needs. The product falls into the class of craft production, but the quantity of the order changes the whole situation. The characteristics of the MRAP production at BAE Land Systems are largely assembly line characteristics based on the Toyota model. We would like the newly designed system model to be based on lean manufacturing principles. Characteristics of lean manufacturing must form part of the core in the new system.

JIT manufacturing must also be taken into account to ensure that the characteristics of lean manufacturing are present. This mentioned manufacturing approach will ensure that the output of vehicles on the production line is constant and on time if well integrated with the supply chain. The top-bottom approach will ensure that the supply chain and the lean manufacturing characteristics namely JIT manufacturing will be well integrated. One of the problems that will be looked at is that of irregular finishing of stations on the line. The shifting of stations must happen on a timely basis at the same time. Bottlenecks would occur if there is no work balancing and if bottleneck monitoring has not been carried out beforehand by using time studies.

If the bottlenecks are sorted out and the production line is working on a JIT principle, then the supply chain can be integrated with the production line. The supplies must be loaded at the warehouse and moved to the stations. The best way to evaluate this technique is to firstly implement it on a small scale. It will also help with the implementation stage of the system if the system is implemented stage by stage. Implementing all 13 stages at once will “shock” the system and result in a chance of bigger cost implications than implementing one or two stations at a time. The implementation of a trolley system can be utilized at all the other production lines in the plant. The trolley system will consist of tuggers pulling trolleys with supplies and will be placed on a predetermined location next to the production line.

There would be no use for the Kanban system because of the approach that is going to be used. The currently used card system showing that supplies are low must be exchanged with a scheduled system. The levels on the trolleys and the frequency of trolleys leaving the loading bay will be predetermined and must be integrated with the lean manufacturing approach of the production line.

The warehouses will be rearranged. The supply chain stage which comes before the materials handling but after storage will ensure that the trolleys are loaded on time. The above mentioned falls outside the scope of work for this project. Communication with that department is crucial to sustain the “top-down” approach.

All the changes in the system will not incorporate changes in the number of workers. The company does not want to lay off workers and neither wants to appoint new employees.

6.1.3. Collect relevant data

Time studies were done on all the stations to find the potential bottleneck "candidates" in the production line. Each station activity list is found in the Appendix A. The times for each station to complete the job are as follows.

Station	Time to complete job
Station-1	0:46:31
Station-2	0:42:46
Station-3	1:21:00
Station-4	0:51:12
Station-5	0:53:28
Station-6	1:57:57
Station-7	0:41:48
Station-8	0:58:14
Station-9	1:12:31
Station-10	0:54:29
Station-11	0:53:23
Station-12	0:45:11
Station-13	0:47:38

Table 2: *Time each station spends to complete job*

Further investigation showed that station 6 comprised of two parts. The first part is a sub-assembly station that assembles a range of valves. The second part at the station is the installation of the valves and the connection of the pipes to the valves. A Full list of activities can be seen in the Appendix A. Further time studies were done on station 6.

The time it takes fitting the pipes are as follows:

Activities	**Time**
Valves connect	0:11:05
Sorting of pipes	0:14:45
Connecting pipes at the front	0:42:27
Connecting pipes at the back	0:53:20
Total time=	**1:57:57**

Table 3: *Activities at station 6*

The sub-assemblies data are as follows:

Sub-assembly	**Time for completion of assembly**
Compound relay valve	0:18:12
Trailer control valve	0:16:20
T copper block	0:02:57
Quick release valve	0:06:10
Hand brake valve	0:03:18
Foot brake valve	0:08:34
Back ABS valve	0:16:25
Air dryer	0:01:11
Front tow couplers	0:05:31
Emergency valve	0:03:34
Air tank	0:02:20
Back tow couplers	0:10:10
Miscellaneous assemblies total	0:07:55
Total	**1h42:37**

Table 4: *Sub-assemblies at station 6*

Station 3 consists of three sub-assemblies and the fitting of those parts with the air-conditioning into the vehicle. Time study can be found in the appendix B.

Station 9 consists of fitting pedals into the car miscellaneous tools and lighting to the outside of the vehicle.

6.1.4. Analyze data

Let us use the average as a benchmark, to serve as a factor to schedule the production line. The average time for each station to complete its job is 58:56 minutes. It is clear in table 3 that stations 3, 6 and 9 takes more time to complete their jobs and that these stations will impede progress on the production line if the scheduled time is situated around the average time. It has also been observed that much time is wasted to find the correct parts to finish the sub-assemblies. This problem will be solved with the JIT approach.

Station 3- There is a need to bring down the time for station 3 to complete the job at hand to allow the workload of the station to fit into the required schedule. The moving of work load to station 1 and station 2 should be investigated to determine what work can be shifted.

Station 9- Work balancing would not be difficult because much of the work is being done on the outside of the vehicle and station 7 has the time to add the miscellaneous parts to the outside of the vehicle. Station 7 will finish the extra work of adding the miscellaneous parts faster than station 9 because station 7 has four workers at the station and station 9 has only three workers.

Station 6- This station is divided in two parts that work parallel to each other. The sub-assembly takes 1h42:37 and the connecting of the pipes takes 1h57:57. The station consists of three workers: one to assemble the sub-assemblies, one to connect the pipes and one who acts as a runner. The latter is assigned to ensure that station 6 is never short on supplies because the company has identified station 6 as a “problem” station. The integration of the supply chain and the lean manufacturing will ensure that the runner is not needed. That will result in an extra hand at station 6 who will come very handy. The space inside the bonnet is very confined and restricts the connection of the pipes only to one person. The connection of the pipes at the back can only be done if the pipes are already connected to the front. Thus only one person can do the connection of the pipes (front and back) on the vehicle. The connection of the pipes takes twice as long as the proposed scheduled time. Thus two vehicles would need to be done in parallel to fit into the proposed scheduled time.

The time that the sub-assemblies take would also need some attention in order to reduce the assembly time to bellow 60 minutes. The time study confirms that the vice takes the most time to assemble. The vice needs to be screwed in and out to re-grip the valves to assemble each valve. A new grip tool needs to be designed to reduce the time it takes to assemble the valves.

7. SOLUTION

The key to the success of this project lies in the systems engineering approach of this system.

Systems engineering approach- The designing will need to follow the “vee”-model based on the top-down approach and starting at the main system.

7.1 Define new system

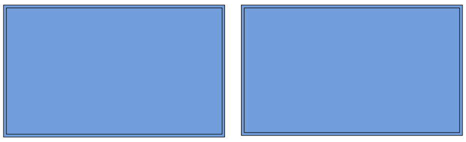
The main system consists of the supply chain management and the production line management. The responsibility of the supply chain management is only handling of the materials from the warehouse to the production line. Both sub-systems work to the same goal, which is to be effective and ensure vehicles leave the last station at a fast rate. Integration of these sub-systems is crucial in order for the combined goal to be reached. The design of each sub-system must be done in such a manner that it incorporates the other one as well.

7.2 Sub-systems

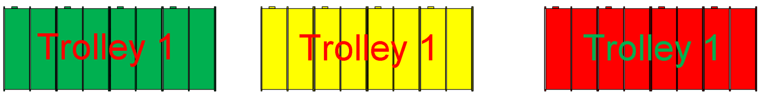
Each sub-system comprises components that are interlinked. The changing of one component will have an effect on other components in each sub-system. Solutions for each sub-system are documented below.

7.2.1 Supply chain management model

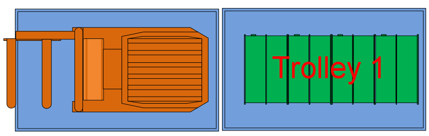
The production line will work on a lean manufacturing approach. The supplies on the production line will be kept at a minimum. The parts and consumables will be supplied just in time for assembly on the production line. Each station will have two designated trolley spaces.



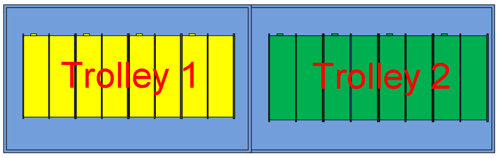
The green trolley represents a fully loaded trolley, the yellow represented a nearly empty trolley and the red trolley represents an empty trolley.



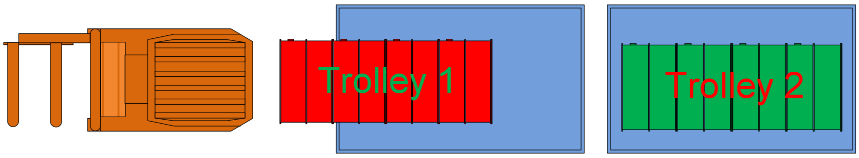
A fully loaded trolley (trolley 1) will be placed on the one designated space the first time the tugger passes by.



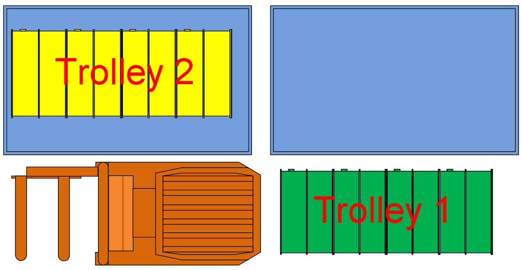
A replacement trolley (trolley 2) that is also fully loaded will be placed next to the nearly empty trolley (trolley 1) on the second time the tugger passes by.



The empty trolley (trolley 1) will be removed to be reloaded on the third time the tugger passes by and trolley 2 will be shifted to the other designated area.



The fourth time the tugger will bring a fully loaded trolley (trolley 1) and place it again next to the nearly empty trolley (trolley 2).



Supply to each station

The supplies at each station (parts and consumables) come in different shapes and sizes. All these shapes and sizes can be incorporated by using different trolleys. Following is an example of some of the trolleys.

There are two options related to the trolley and tugger system. The first is to choose the trolley that fits each station best and use only that trolley for that station, or use uniform trolleys and work with the shapes and sizes to resolve the problem by designing the system around these obstacles.

Scheduling a system with uniform trolleys will be much easier than using selected trolleys for selected stations.

Trolley system design

It has been decided by the management of the company that the Wesley Industrial trailers will be used, because of the dimensions of the trailer. All supplies of station 1-7, 9 and 11-13 can fit at least a load of 1 vehicle's supplies on a trolley, except station 8, 10 and station 7. Station 8 is the mounting of the engine into the bonnet, which is done by means of an overhead crane. At station 10 the petrol tank and outside bins that are brought on a JIT approach by means of a forklift are being connected. The axis are stacked on racks and also brought by forklifts to the production line at station 7.

At the loading bay each trolley will have a recipe to identify which parts will be loaded onto the trolleys. Two loading bays will be allocated, one at each warehouse. The trolleys of station 1-7 will be loaded at the first warehouse and the trolleys of station 9 and 11-13 will be loaded at warehouse 2.

The maximum number of trolleys a tugger can pull in the plan are three. The constraint is placed on the trolleys not because of the weight of the trolleys but because of the dimensions of the plant and the tuggers. Tuggers pulling more than three trolleys are not able to make the turns in and out the plant as needed.

It has been determined that all stations can fit the supplies of at least one vehicle on a trolley, where station 3, 6, 9 and 11 can fit supplies for two vehicles on each trolley. The stations are divided into groups so that there are three trolleys that can be delivered together. Group 1 consists of station 4, 5 and 7. All three of these station trolleys can fit only one load. It would be better to bunch these stations together. Group 2 consists of stations 1, 2, 3 and 6 and group 3 consists of stations 9, 11, 12 and 13. These two groups have four stations each, because in these cases both groups two and three have two stations each that only need supplies every second time the tugger passes. The tugger will alternate between these two stations every time it drops-off supplies or pick up the empty trolleys.

Each cycle takes an hour, similar to the schedule that governs the production system. (Will be discussed in chapter 7.2.2) All fully laden trolleys must be dropped off before the end of a cycle. The empty trolleys can be collected in the beginning of the next cycle. Thus each group will have 2 trips, resulting in six trips in total. It has been determined that each tugger can complete 4 trips in 60 minutes. Group 1 and 2 will be supplied by one tugger and group 3 will be supplied by another tugger.

7.2.2 Production Scheduling

The production line will work on a scheduled basis. Each vehicle will move from one station to the next on an hourly basis. A window of 10 minutes will be allowed after each hour to move the vehicles to the next station. In addition it will assist in completing unfinished work difficult circumstances that may occur when the work is not finished during the designated time frame.

Station 3- There is a need to bring down the time for station 3 to complete the job at hand to allow the workload of the station to fit into the required schedule. Station 3's time stands at 1:21:00, station 1's time stands at 0:46:31 and station 2's time stands at 0:42:36.

Station 1 must unpack the condenser, connect the air pipe, tighten the air pipe bolts and spray the lubricant which would take an estimated 10minutes off station 3's time. This work balancing can be done because the work load moved does not rely on the work that is done at station 2.

Station 2 must attach right and left hand air units to vehicle and insert hoses into the nose of the vehicle. The work load that is moved away from station 3 to station 1 and station 2 totals 21 minutes. The fetching of the pipes that took 2minutes will not occur again because of the JIT approach of the production line. That places the time that station 3 takes to finish their job below one hour.

The same approach is used to balance the work load from station 9 to station 7.

A change in the layout of station 6 will be made so that station 6 can be used in the production line more effectively. This means that two vehicles will be stationed at station 6 (A + B). The third person at the station serving as the runner will be trained to connect the pipes on a second vehicle, which was not the case up to now. The moving of the vehicles from station 5 will alternate between station 6A and station 6 B. This means that the pipes of two vehicles will be fitted at the same time at station 6. Each worker will have two hours and 10 minutes to finish his job because the vehicle he is working on will not have to be moved after the first hour because the vehicles will stand next to each other. That would give the worker more than enough time to connect the pipes to each vehicle.

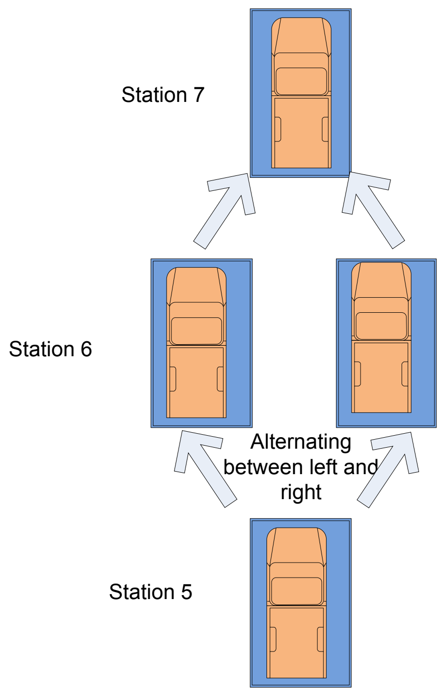


Figure 3: Redesign of station 6

7.2.3 Optimization of the sub-assembly line

Time studies had shown that the vice wasted too much time as a result of the opening and closing of the vice every time a new screw or bolt needed to be screwed in (appendix B). It must be ensured that the assembly of the valves is completed in less than an hour, so that it can conform to the new production system. This could be done through the design of a new gripping tool to replace the vice. The new gripping tool will be in the form of a jig. Each valve will have a jig that will hold the valve in place, while the worker assembles the valve. A fitting at the bottom of the jig will fit over a square steel pipe to clamp the vice. Multiples of the same valves can be assembled consecutively to save time.

Designing of the jigs

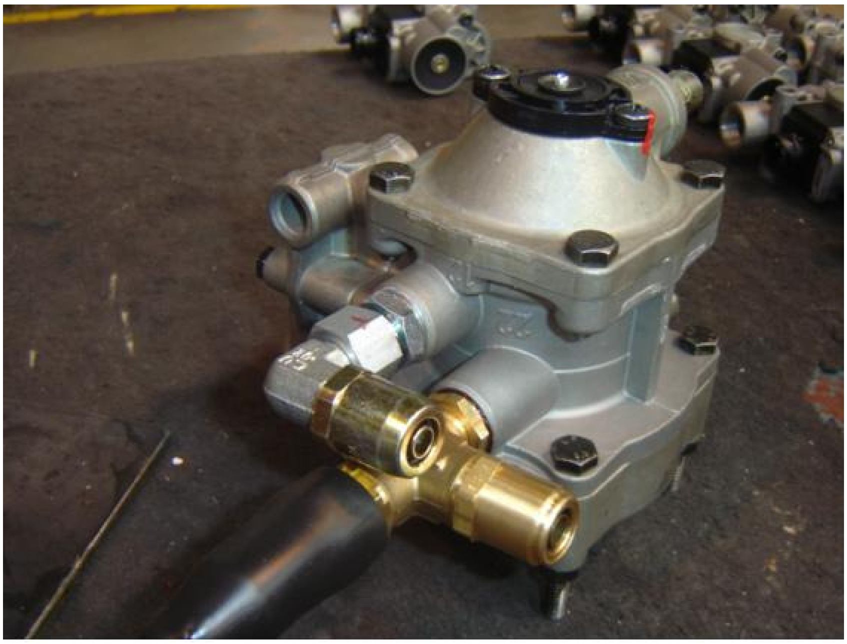
The jig needs to hold the valve in place while the screws, nuts and bolts are screwed into the valve. The valve must be held in such a position to allow for the assembling to be done without moving or changing the position of the valve. The valve must also be locked in position so that it does not rotate in the same direction as the twist of the screwing.

Example of some of the valves-

1. Compound relay valve

2. Foot valve

3. Trailer control valve

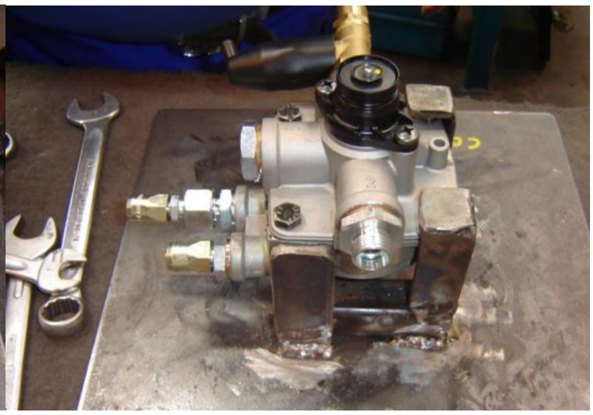


4. Back tow couplers

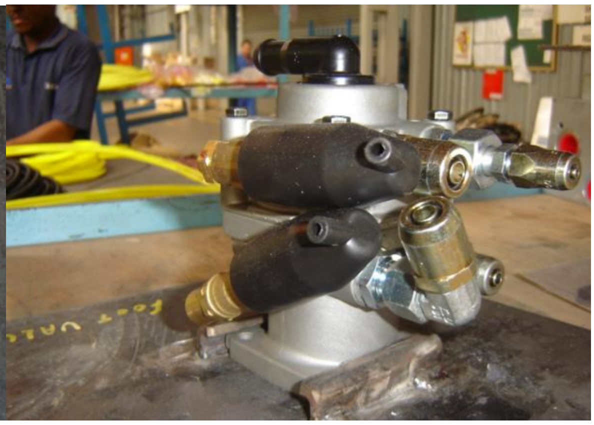
Each valve is unique and will need its own jig to fit its valve. The results can only be determined after the jigs are designed and implemented.

Examples of the jigs with the valves inserted-

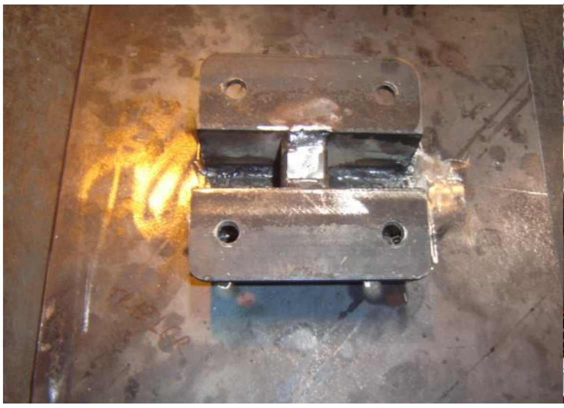
1. Compound relay valve and jig



2. Foot valve and jig



3. Trailer control valve and jig




4. Back tow couplers and jig


Subassembly	**Time for completion of assembly**	**Time for completion of assembly with jig**
Compound relay valve	0:07:55	0:05:13
Trailer control valve	0:16:20	0:08:06
T copper block	0:02:57	0:02:57
Quick release valve	0:06:10	0:03:57
Hand brake valve	0:03:18	0:02:18
Foot brake valve	0:18:12	0:08:15
Back ABS valve	0:16:25	0:08:11
Air dryer	0:01:11	0:01:11
Front tow couplers	0:05:31	0:03:21
Emergency valve	0:03:34	0:02:04
Air tank	0:02:20	0:02:20
Back tow couplers	0:10:10	0:04:53
Miscellaneous assemblies total	0:08:34	0:06:11
Total	**1h42:37**	**0h58:57**

Table 5: *Subassemblies at station 6 with jigs*

8. CONCLUTION

The objective of the project is to optimize the production line by means of implementing a tugger and trolley system, in addition to implementing other industrial engineering tools. Serious system redesigning needs to be considered and implemented for BAE Land Systems SA to keep up with their demand and requirements. There is a need to look at the efficiency of a new supply system with the help of Industrial Engineering techniques, such as Supply Chain Management, time studies and the implementation of JIT systems. Optimization can be applied, ensuring better results at the end of the project.

The objective of the literature study is to determine how other companies have implemented similar solutions and what approach they have utilized to reach their conclusions. The content of the literature study covers the current practice of BAE Systems and includes an historical review about the trade within which BAE is functioning. It also includes a case study, which resembles BAE Systems trade and covers two problem areas in the field of automobile manufacturing, namely bottlenecks and Supply Chain management.

The production line has undergone work balancing to ensure that the production line will shift every hour. While some stations only need balancing of work, other stations – such as station 6 - needs redesigning of their tools to ensure work to be completed within the hour. The supply chain has been conformed to fit the production line by implementing tuggers and trolleys to supply the stations with materials and consumables. A top-down approach is being used to ensure good communication between these two systems.

BAE systems only produced 3-4 vehicles a day before this project began. However, as a result of this study, BAE is now producing up to 8 vehicles per day - an improvement of nearly 100% on their daily productivity rate.

REFERENCES

ADAMS, J., BALAS, E., ZAWACK, D., The Shifting Bottleneck Procedure for Job Shop Scheduling, Vol. 34, no.3, 1988.

AXELROD, R., Simulating Social Phenomena. Berlin: Springer, pp.22-40. 1997.

BILLINGTON, C., Strategic Supply Chain Management, pp. 20-27. 1994.

BUIL, R., PIERA, M. A., New warehouse design methodology at strategic and operational level, 6th WSEAS International Conference on SYSTEM SCIENCE and SIMULATION in ENGINEERING, pp.196. 2007.

BURNS, L. D., DAGANZO, C. F., International Journal of Production Research, Volume 25, Issue 1 pp. 71-99. 1987.

BRAIDEN, B. W., MORISSON, K.R. Lean Manufacturing Optimization of Automotive Motor Compartment System, Computers Ind. Vol. 31. pp. 99-102.1996.

BRATLEY, P., FOX, B. & SCHRAGE, L., A Guide to Simulation, Second Edition, New York: Springer-Verlag.1987.

CHAN, F. T. S., SMITH, A. M., Journal of Manufacturing Systems. Vol.12, Iss.3, pp. 239. 1993.

DANKBAAR, B. Economic crisis and institutional change. Maastricht: Universitaire Pers Maastricht, 1993.

DANKBAAR, B., Extension of Sociotechnical Systems Design, Human Relations, Vol. 50, No. 5, 1997.

ELLEGÅRD, K., ENGSTRÖM, T., & NILSSON, L., Reforming industrial work. Principles and realities in the planning of Volvo's car assembly plant in Uddevalla. Stockholm: Arbetsmiljöfonden, 1992.

FORSBERG, K., MOOZ, M., COTTERHAM, H., Visualizing Project Management, 2nd Edition, Wiley, 2000.

HOUNSHELL, D. A., From the American system to mass production, pp. 1800-1932. Baltimore/London: The John Hopkins University Press, 1984

KELLNER, M. I., MADACHYT, R. J., RAFFO, D. M., Software Process Modeling and Simulation: Why, What, How," Journal of Systems and Software, Vol. 46, No. 2/3, 1999.

LALK, J., Systems Engineering, Introduction to Systems Engineering, 2003.

LIDOW, D., Supply Chain Network, 2002.

LIN, F., Reengineering the Order Fulfillment Process in Supply Chain Networks: A Multi-agent Information Systems Approach, 1996.

LIKER, J. K. 2004. The Toyota Way: 14 Management principles. United States of America: CWL Publishing. pp. 330. 2004.

SHAW, M. J., Simulation of Order Fulfillment in Divergent Assembly Supply Chains. Journal of Artificial Societies and Social Simulation. Vol.1. 1998.

TRAINED, G., Material and Logistics Management. 1996.

WOMACK, J. P., JONES, D. T., ROOS, D., The machine that changed the world. New York: Rawson Associates. 1990.