A review of operational efficiency and waste reduction opportunities for a JIS production system—a case study

Neil Chappell[1]

Acknowledgment

The author would like to thank Dr Karen White, who assisted with editing & preparation of the case study for publication.

Privacy Statement

All people interviewed and observed for this research project have been afforded complete anonymity throughout the paper. All participants in this research have agreed to participate without any limitation beyond anonymity. There is no reference in the project to age, gender, religion or any individual characteristics of any of the people being interviewed for the project. All people observed and interviewed for this project research have signed Research Consent Forms and have agreed to their feedback being used in this article. The company that is the focus of the research project has agreed to being used for this purpose and to the article being published.

Abstract

For ZF Australia to remain competitive in the automotive industry, and provide employment for the future in a declining market while providing a return on investment for the parent company, the plant needs to make some changes to their operational processes. Continuous improvement needs to be carried out, processes re-aligned and waste that inevitably builds up over time must be reduced.

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ZF is a Just-in-sequence (JIS) manufacturer of automotive assemblies, supplying to Australian vehicle manufacturers. It is a dependent demand facility which relies completely on the request signals that are sent from the customer two hours before the finished product is required. In the 6 years since the plant was set up demand has decreased substantially, yet the manufacturing line and sub-assembly cells have largely remained unchanged.

Through this research, undertaken on the production line, an operational process that requires both line balancing and a complete shift of the manufacturing cell has been identified. This process is a stand-alone metal pressing station that feeds a sub-assembly area adjacent to the main production line. The recommendation out of this research and analysis is to incorporate this off-line assembly cell into the sub-assembly cell that it feeds. This will allow the line operator to run both cells and manufacture only what is required. In other words, this will provide Just-in-time support to the next customer in the internal supply chain.

As a result of the shift, waste in the form of sub-assembly buffers and excess movement by operators and forklifts is removed from the process. It also enabled the reduction in headcount of one operator. Should demand increase, there is the flexibility of increasing headcount and re balancing the line without the necessity of shifting equipment.

Keywords: Just in time, JIT, just in sequence, JIS, automotive, manufacturer, process management, waste

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Introduction

Operations and Process management is the management of resources and processes that produce finished goods, products and services. This applies to all types of businesses, regardless of the level of processing that is undertaken. As Slack, Chambers, Johnston and Betts (2009, p.4) state *'All businesses have 'operations', because all businesses produce products and services or some a mixture of both'*. The effective management of operations and processes has a strategic impact on the business as it has a direct influence on cost, output and ultimately profitability. While processes across differing types of operation are not all the same, it is possible to use a common framework to design and manage the operations.

On the other hand, the demand model of the industry (in this case automotive) and the particular business will have an impact on how the processes will need to be managed, particularly looking at what is referred to by Slack (2009, p.21) as the four Vs of processes.

The four Vs, are ***volume, variety, variation***, and ***visibility***. The implication is that where the company is able to produce at high volume with low variety of products being produced in that process, with low variation of the process and low visibility of the processes, it will be able to lower or reduce the cost base. This four V model has substantial impact in the design of process layouts, process technology and job design.

The purpose of this research is to assess the ZF Australia plant by analysing the current setup with a view to assessing possible improvements to the manufacturing process. These improvements are necessary due to the changes that have taken place in the business model and the fact that the criteria at the set up stage has changed significantly.

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Background of the research

Manufacturing plants are sometimes set up based on demand from predominantly one customer. Where the possibility of entering a new market through an acquisition does not exist, these plants tend to be greenfield operations in specific chosen areas of expertise of the parent company: where the parent company starts a new venture by constructing a new operational facility (Hill 2007). This is further compounded when the plant is set up for high volume, low variety and with the complexity of being a Just-in-sequence (JIS) manufacturer.

JIS companies manufacture to customer specification after receiving an electronic build signal which supplies details of what is to be built. The finished product is normally required within a short and set time frame, to be delivered defect free to a specific point within the customer's production facility for fitment to the customer's product. Many companies are set up as Just-in-time (JIT) operations, giving them more flexibility and less risk of being in a position whereby they cannot complete the process in time. JIS is often confused with JIT as there are significant similarities, and there are not many true JIS companies in existence. The major difference is in the allowed delivery time from order trigger and in buffers of finished goods ready for dispatch. JIS traditionally does not allow for any buffer of components or finished goods while JIT seeks to eliminate unnecessary buffers but may have a certain amount of key stock and finished goods in the process (Slack et al. 2009).

ZF Australia is part of a large multinational group with similar plants around the world. The ZF facility was set up specifically to produce the assemblies for a large original equipment manufacturer (OEM) of vehicles in Australia. The plant was designed as a JIS plant able to deliver 180,000 modules per annum on a three shift (24 hour) model. The ZF plant is the only true JIS automotive parts assembly plant in Australia, relying on a signal being sent electronically via Electronic Data Interchange (EDI) when the vehicle body shell enters the paint booth at the OEM.

EDI is an electronic transfer of information between different computer systems which was set up in the days before the Internet was available for data transfer between business partners (Evans & Lindsay 2005). Once this EDI trigger is received, ZF has 120 minutes to manufacture a complete front and rear assembly and have it ready for loading on the dedicated OEM transport for direct delivery to place of fitment on their production line. There is limited margin for error and any issue at ZF could stop the entire OEM manufacturing plant. In the automotive industry this is a major incident and comes with severe cost penalties.

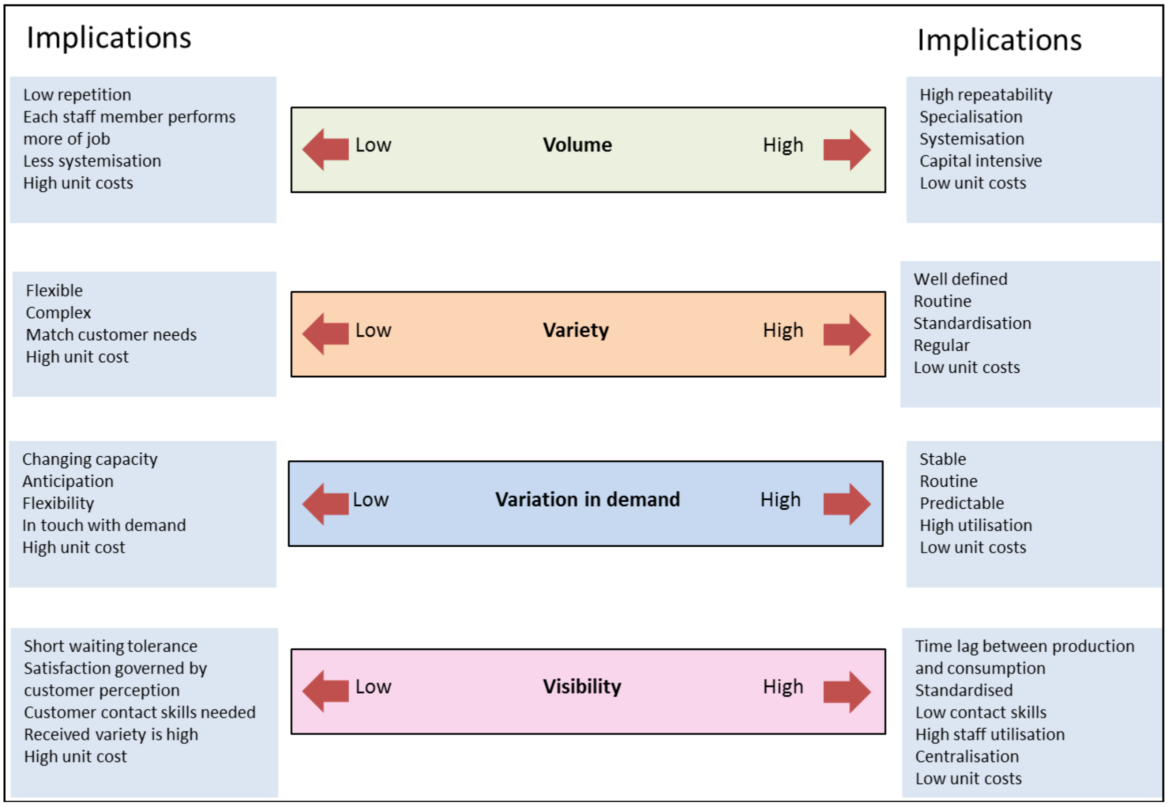
Even though ZF was set up for the three shift model, the OEM has never been able to achieve this and has reduced their year on year output to the 2011 volume of around 65,000 vehicles per annum over a two shift split. In 2008, the OEM moved to a one shift model, producing almost the same number of vehicles as they had previously produced over 2 shifts with a marginal improvement in profitability for ZF, which slightly offset the losses due to reduced production numbers from the planned 180,000. To compound the decrease in volume, the OEM has increased the number of options available on the vehicle which has increased the number of variants that ZF must be able to supply. As a result of the move back to 2 shifts in 2010, with lower output volumes and increased variety, the ZF highly automated mass production facility is underutilised and there are inefficiencies in the process.

As the plant was set up specifically for the OEM as a one customer JIS plant there is limited scope for changes to the shift model, to speed up the overall line or to remove operators on the continuous production line. ZF is contracted to manufacture the particular assembly variant called up via EDI and to supply JIS as required by the OEM at their prevailing line speed. Most of the production stations are required to have an operator present and cannot share an operator with the previous or next work station. There may be fairly long periods of time that the operator at a particular station can be doing nothing due to a particular vehicle variant not being signalled for build. While it is not possible for ZF to change from a JIS system or 2 shift model or to make significant changes to the production line, it may be possible to make changes to the process layout—in particular the process technology and the individual processes feeding the production line—that could improve profitability, efficiencies, reduce sub-assembly buffers, reduce movement and possibly reduce headcount in some ancillary processes.

An important consideration in the process layouts, the process technology and the job design is the impact of the four V model, presented in Figure 1 below. In a manufacturing operation, the process type is most applicable to the volume-variety relationship. The company could manufacture: according to a specific project where there is very low volume with high variety; as a jobbing based business where there is still high variety but slightly more volume; as a batch build type of business with higher volume and less variety; or as a business that is able to mass produce. The mass production business type, typical in the automotive manufacturing sector, has little variety and high volume, or it may be set up using continuous processes if it has the least variety and highest volume. Likewise, volume-variety will directly influence decisions on process layout, process technology and the level of investment in these areas. A business will generally not spend the high amount of money required to automate a high variety, low volume process. When the ZF plant was set up, it was considered a high volume, low variety process which justified the expense of the highly automated continuous process manufacturing line. This has changed with the addition of many vehicle variants and significant reduction in volume of vehicles being manufactured.

ZF uses a production philosophy known worldwide in its plants as the ZF Production System (ZFPS) which is based largely on the Toyota Production System (TPS). The Toyota Production System has a strong focus on being lean and on the reduction and elimination of waste. TPS emphasises Kaizen and Gemba as fundamental parts of the process. "Kaizen means improvement" (Slack et al. 2009, p.440); this concept takes a process, breaks it down, removes the unnecessary parts and then puts it back together in a more efficient way (Evans & Lindsay 2005). "Gemba, means the actual place" (Gemba Academy 2011). When performing Kaizen activities, the participants must go to the "actual place" (Gemba), that is earmarked for improvement and visualise firsthand the process that takes place. TPS and the ZFPS promote this visual direct approach to continuous improvement of activities by looking at actual parts, production areas and issues; that is experiencing the process directly (Gemba Academy 2011).

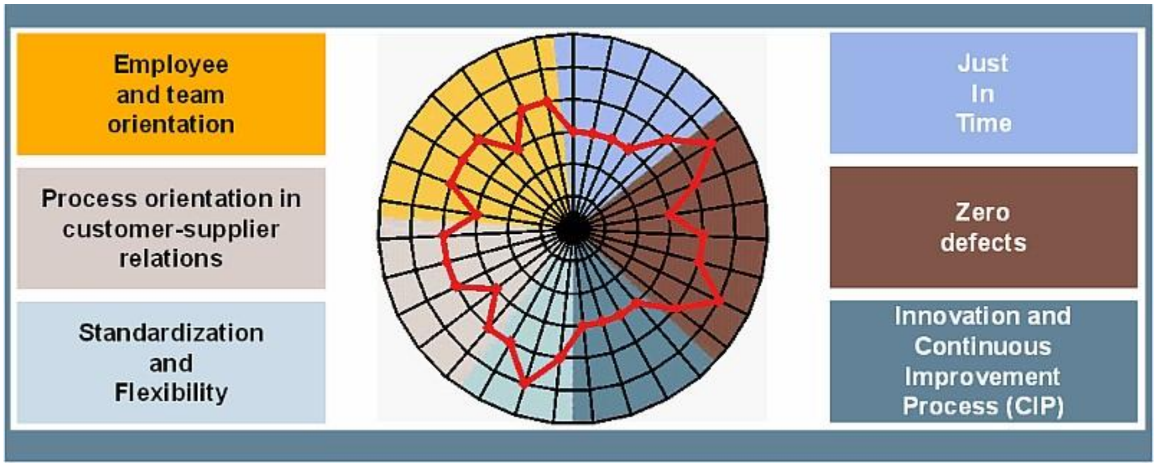
Figure 1 **The 4 Vs—a topology of operations**



Source: Slack et al. 2009, p.23

Figure 2 shows the outline of the ZFPS measurement system. ZFPS Lean Management personnel from the parent company carry out Lean assessments at every manufacturing location each year in conjunction with the management team from that location using this scoring model. It is a matrix broken down into six key areas, each of which has a series of questions and metrics that are used at each location in the same way to ensure valid comparisons and to identify areas for improvement in an individual location. The scores are then used year on year to show improvement and to highlight areas of focus for improvement activities.

Figure 2 **The ZFPS Measurement outline**



Source: ZFPS International Manual 2011

Represented in Figure 2 is an example of a possible score in a ZFPS audit. The example shows room for improvement in the areas of JIT and Continuous Improvement and better results in employee and team orientation, as well as in process and zero defects. Certain aspects of zero defects and standardisation show near benchmark results. Waste is a major focus within ZFPS and of any production system derived from the original TPS. In business, waste can be referred to as any activity that does not add value. (Slack et al. 2009, p.352). At ZF, through the regular management Gemba walks, possible areas for improvement and reduction of waste have been identified in various departments and manufacturing processes. In addition, the annual Lean assessments have identified waste in various processes of the ZF Australian plant. The results of these assessments have been used in this research to analyse the process, choose an area of focus and formulate the questions used in the interviews (ZF Lean assessments 2010 & 2011).

The results show that the bulk of the waste within ZF is in the operations process. This waste is present for various reasons: predominantly due to the previously mentioned reduction in demand since the plant was commissioned; the company not being able to rebalance the line to this reduced demand; and a slower production line speed or Takt time of the JIS customer.

Liker (2004, p.55) defines Takt time as “the tool to link production to the customer by matching the pace of production to the pace of actual final sales”. In the case of ZF, final sales are at the time the JIS product leaves the plant on the OEM truck.

Examples of some of the waste identified at the ZF Australia plant are:

- excess stock in raw material, Work in Progress (WIP) and sub-assemblies;
- excessive movement by logistics personnel shifting stock around the plant; and
- excessive movement by production personnel in their manufacturing cells and moving WIP to the next process.

This confirms that the process at ZF Australia does not meet the demand of the customer as efficiently as it would if the volumes and customer Takt time were at the levels that the plant was set up for. While the ZF plant was set up with a lean focus, it was never designed with an agile supply network in mind as there was an expectation of set volumes per annum and predictable demand for each variant. Slack (2009, p.370–373) refers to agility as “responsiveness from one end of the supply chain to the other” and on “elimination of barriers to quick response”. At ZF Australia, there has not been regular line balancing and layout changes and some of the workstations are no longer synchronised with the requirements of the line and customer demand. Slack (2009, p.352), states that “Lean synchronisation aims to meet demand instantly with perfect quality and no waste”. With this in mind, the process can no longer be considered as lean synchronised.

While looking at the lean synchronisation of the plant, consideration needs to be given to the agility of the total supply chain. At time of setup of ZF Australia, an agile approach would not have been considered due to the assumptions of set demand with low product complexity. As can be seen in Figure 3, the annual volumes of Australian OEMs have declined over the past six years and demand has been far from certain. Figure 3 shows the month to month demand changes based on actual vehicle sales, which adds to the planning complexity. This variance in demand would justify an agile approach. As Slack (2009) discusses, where product variety is high and demand is low an agile approach can help a business cope with the instability. Using ZFPS, a combination of the lean and agile philosophies, which is referred to as a leagile approach, would be appropriate for ZF Australia despite the actual business model not meeting the criteria of low demand uncertainty (Slack et al. 2009, p.372–373).

Figure 3 **Annual Australian OEM production for all manufacturers**

	2007	2008	2009	2010	2011	2012
January	18,666	21,152	11,941	13,086	12,498	14,252
February	29,376	32,303	20,404	23,047	18,600	22,860
March	29,433	26,393	21,310	25,738	20,155	19,578
April	22,633	28,721	12,792	20,239	16,195	15,138
May	33,274	35,180	16,842	23,559	17,898	21,504
June	29,195	29,884	18,674	21,794	21,780	19,553
July	31,813	33,121	17,864	18,558	20,413	20,608
August	27,713	29,397	16,988	20,088	24,320	22,981
September	28,563	28,511	20,924	21,364	16,814	18,201
October	33,320	24,119	23,551	19,369	13,600	18,835
November	29,746	20,659	22,622	19,594	19,856	17,245
December	21,040	14,678	19,442	13,007	17,247	10,469
Total	334,772	324,118	223,354	239,443	219,376	221,224

Source: FCAI Monthly production volumes January 2013

Through this research with the focus on a particular process, the aim is to address these key questions:

1. Is the current production setup at ZF optimal for the output and return that is being generated?
2. What is the impact to the process due to changes in demand since the plant was commissioned?
3. How does the plant layout contribute to waste in operations?

4. Using one process as a research base, what can be done to improve the situation, if proven that there is a need for change?

The research looks at optimising the layout in one assembly area of the automated production line and the resultant improvements that can be made in the overall Supply Chain. The process researched is the largest offline process work cell adjacent to the assembly line, with 4 fulltime operators and a halftime logistics line filler dedicated to movement of stock in this area. This particular process has more waste than most of the processes in the operation. The process is called Rear Wheel End 10, or RWE 10. This is an offline process cell which is comprised of two presses pushing rubber bushes into cast iron knuckles. The research determines how to maximise the process and reduce or minimise waste.

Research methodology

This research was conducted as a single case study. Yin (2008) mentions that one of three qualifying criteria where a single case study can be justified is where a researcher is an employee of the subject firm with the requisite access to all data. Morris and Wood (1991) state that the case study strategy will be of particular interest in gaining “a rich understanding of the context of the research and the processes being enacted” (Saunders, et al. 2009, p.146). As an employee of ZF Australia, a single case study strategy has been used as the researcher has access to readily available data and personnel at all levels.

Surveys for self-completion were initially considered to gather data but, given the production environment and demographic, it was decided that personal one to one semi structured in-depth interviews would be conducted (Saunders et al. 2009, p.320). The questions were tailored to the type of role being interviewed and the personal approach produced more beneficial results. Previous experience in getting personnel to complete surveys has shown that data gathered may not be representative of the larger group. Few people complete the surveys, the responses are geared towards individual's preferences and mindsets, and many people do not take them seriously. The more hands-on approach was therefore used throughout the case study, including first hand observation of processes, direct verbal interviewing of the personnel in the plant and telephonic and email discussions with personnel external to the plant. The interviewees included the process operators, management, supervisors, engineers and members of expert panels at ZF head office.

ZF Australia is regularly visited by representatives from the parent company and the researcher was able to interview some of the ZFPS and head office engineers in person. Head office engineers were interviewed because they had insight into why the plant was set up as it was and they have experience of similar ZF plants around the world. In addition, ZF Australia being a small plant in a global company, any significant line changes that are made would require sanction from head office. The ZF lean experts were interviewed because they carry out surveys at the plant and travel to ZF assembly plants around the world and are able to share these experiences. The other people interviewed have relevant roles within the current ZF Australia operation.

For this research, ZF Australia granted direct access to data, personnel and operations processes, and allowed discussion groups to be held using the company's facilities. Given this access, the preferred methodology was both the direct interview and, at times, a structured observation approach. This was due to the accessibility to the organisation, sufficient time for the study and the ability to gain the trust of the people in the process. Confidentiality of the respondents was assured through the survey not using any individual names in the report and the Research Consent Forms being kept only by the researcher. Structured observation took place in terms of recording actual output, time and motion studies. 'Off the shelf' coding systems were not used due to the specific nature of the operation and the need in this instance to be focused on lean and agile outcomes. The researcher developed a system using the guidelines and checklist in the text to ensure that the checklist was valid and reliable. The threat of observer effect was in part overcome by a portion of the observation of the work cell being done without the operators being aware that it was taking place. Ethically this was acceptable as all operators were made aware up front that this research was taking place, had filled in the consent forms and had the opportunity for feedback and discussion (Saunders et al. 2009).

The advantages of the researcher being not only an employee but also part of the management team of the organisation were in ease of access as required, knowledge of the culture of the business, the industry jargon, the way the plant is set out and how the informal organisation works. The other members of the management team were initially sceptical and were of the opinion that what was being undertaken was a theoretical exercise which would require a lot of time and yield limited results. Fortunately, over time and through the sharing of data, it was able to be shown that very real gains could be made and that no one was being made to look inefficient through the process. The interaction with the Production Manager in particular was vital to the research. Many of the shop floor interviews included the Production Manager and various scenarios were worked through together. This approach was beneficial in shortening the amount of time that would have been required in explanation, in allaying fears of the individuals on the shop floor and in gaining the participants trust.

The study being a more factual one, and the fact that the researcher was not directly involved in operations on a day to day basis, counteracted most of the expected disadvantages of the researcher being too familiar with the subject of the study. More questions had to be asked that may have been obvious to those involved on a day to day basis with the process. This not only gave a thorough understanding but enabled each step to be questioned and analysed in a systematic manner while gathering the data. This same argument applied to the possibility of the researcher assuming too much regarding findings and the process. The statement by Saunders (2009) that “being from an independent part of the organization requires a deeper, more comprehensive unbiased research methodology” is certainly a valid one. In discussions with personnel, not only involved in the setting up of the plant but also those currently involved in any change activity, process layout decisions and day to day management of the process, it was clear that any improvements being made were extremely minor. People that are directly involved are not always able to look for bold meaningful changes, even where these appear fairly obvious to someone removed from the process (Saunders et al. 2009).

In the interviews, standard questions were used which were tailored to the different areas of expertise of the person being interviewed. All respondents were asked to sign a Research Consent form prior to being included in any research. The target respondents, selected based on their current or past involvement in either the operations process or the overall plant layout, broken down by survey type used, were:

a) Direct face to face interview, discussion and hands on observation of the Process:
   - Operators directly involved in the production cell being looked at;
   - Management of the plant and in the functional areas at head office who were involved in the plant setup;
   - Engineering in the plant;
   - Logistics personnel in the plant involved in the process;
   - ZF global visitors to the Australian plant where appropriate; and
   - OHS Representatives at plant level to give direction on potential impact that any changes could have on safety, the environment or legislation; and

b) Discussions on the phone or by e mail:
   - Engineering personnel in the ZF Melbourne design office;
   - Engineers at head office who were directly involved in setting up the plant;
   - Logistics personnel from ZF head office who were involved in the beginning at plant setup or are currently responsible;
   - ZF Lean experts who may have input from other ZF plants and offices around the world.

Data collection and analysis

There are a number of tools and methodologies for process improvement, including process flow charts, backward chaining, the Deming Cycle, Juran's breakthrough sequence, FADE (Focus, Analyze, Develop and Execute), value stream mapping, Gemba walks, standardised work charts, herring bone (ishikawa) diagrams, and creative problem solving (Evans & Lindsay 2005).

The creative problem solving process is comprised of six steps:

- Understanding the mess
- Finding facts
- Identifying the specific problem
- Generating ideas
- Developing solutions
- Implementation

Backward chaining was carried out using flow charts starting with the end goal of the customer requirements and moving backwards through the process, identifying key steps required to produce each output and finally reaching the start point of the supplier input stage, which is the end point of the chain (Evans & Lindsay 2005). This is helpful to someone not normally involved in the process in being able to see the impact of each step on the one before. If the researcher had not used this approach, changes may have been suggested that could have had an adverse impact somewhere else in the operation.

In the analysis of the data collected, the current process setup was discussed with the design team, manufacturing engineers, the manufacturing manager and people directly involved in the process—operators and logistics personnel. Value stream maps were used as a visual method of showing any waste in the process with a team from different parts of the company.

This gives an unbiased view, different people may pick up items that people directly involved may not and there is an opportunity through 'outsiders' questioning steps allowing others to stop and think about the process. Value stream maps can be referred to at any time and process changes can be visually mapped. It is therefore possible to make calculations of reductions in personnel and inventory, comparing the current state and the future state maps. The value stream maps can then be compared to reality if the suggested future state is adopted (Gemba Academy 2011).

It is interesting to note that of the eight process operators interviewed, seven of them were quick to point out that they could see the amount of waste in the system due to the way that the process was oriented. This is important because it reinforces the principles of TPS of direct involvement of the operators in the process design and in any Kaizen improvement initiatives. To date, within ZF, the layout and any subsequent changes suggested have been top-down initiatives, predominantly driven by Engineering and production management, with limited input from the process operators. The operators showed that they did not want idle time and that they could see the longer term benefit of stability and profitability through increased productivity.

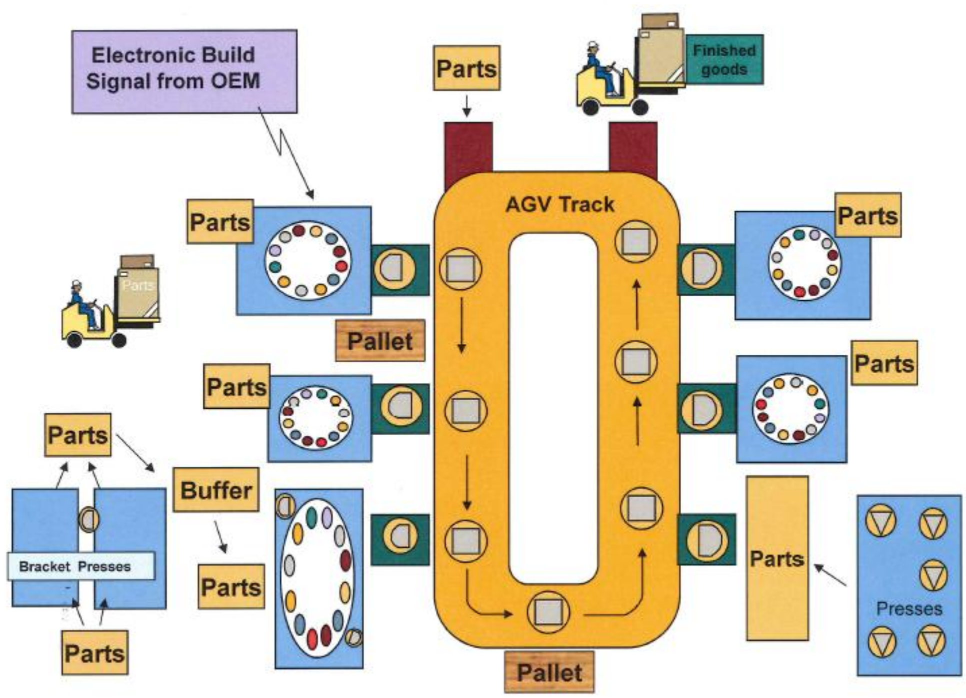
All of the Logistics operators interviewed were of the opinion that they should not be in the production area with their forklifts quite as often, should not be moving the stock around as much as the layout required and could see opportunity for improvement through changing the process layout. This was not only in terms of safety concerns but in most cases, a genuine understanding of the benefits of reduced forklift movement in cost saving. Most operators and logistics personnel had undergone Certificate 3 training in Competitive Manufacturing as well as the ZFPS training. It was rewarding to see that the training had value and that the employees were able to apply their learning in assessing the situation. A significant finding of the research, in terms of the shop floor personnel, was that none of the respondents were fearful of cuts in headcount due to layout changes, pointing out only the benefits associated.

Key Activities, processes and Events

The ZF production line is set up on a continuous track, where at station one the base frame is mounted to an automated work piece carrier known as AGV. The AGV travels along the track and stops at each station where the next operation is performed until it reaches the final station where a robot inspects the final assembly quality and releases the assembly for shipping. Adjacent to the Rear Wheel End 10 press station is a sub-assembly area which assembles various sub-assemblies for later fitment on the main assembly line. This is a continuous production cell which produces a small buffer ready to support the AGV as it arrives in the station.

A simplistic diagram of the assembly line is depicted in Figure 4 with the focus area and the many parts buffers shown in the bottom left of the diagram.

Figure 4 **ZF Production Line**



Source: drawn by Neil Chappell for this research 2011

The research problem is the cell that feeds the parts sub-assembly. This cell consists of two separate presses which require one operator to take a left hand knuckle and three bushes, put these into the auto press and press the start button. He then takes a right hand knuckle and three bushes, puts these into the other press and presses start. By then the left press opens, the part is taken out and placed into a tray, followed by a right hand part into its tray. The operator is producing independently of the line speed or customer requirements and will produce until all of the buffers are full. The press cell showing the left and right bracket presses, the raw parts in front of the cell and the finished goods trays at the end (closest to camera), is shown in Figure 5.

Figure 5 **Photograph of Knuckle Assembly Press Station**

Source: for this research, Chappell 2011

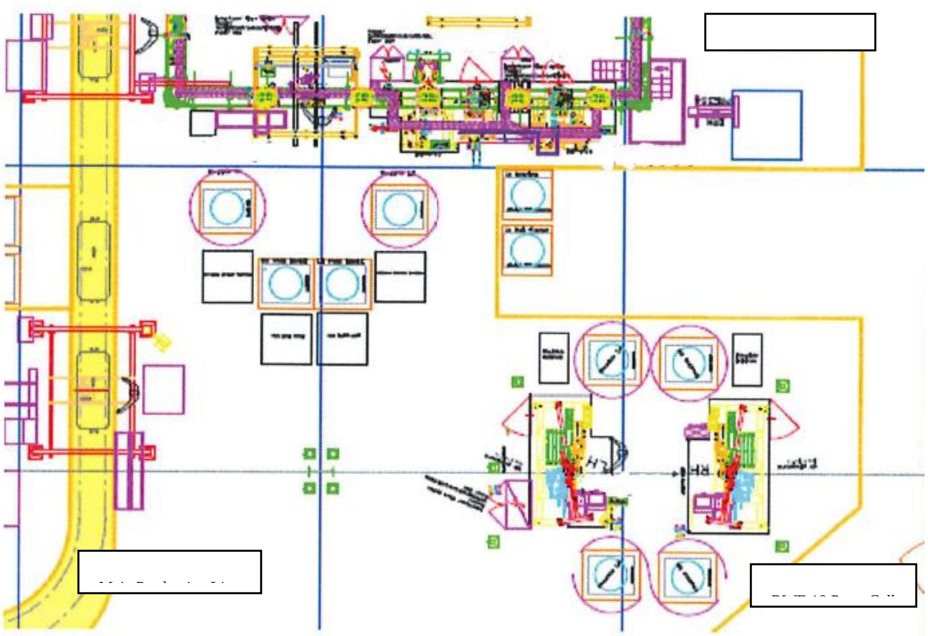
These two layers of finished pressed knuckle trays are the first buffer. In Figure 6 the second buffer of knuckles, located 30 metres away from where it will be used, can be seen. When the left and right hand knuckle trays in front of the presses are full they are moved to this buffer by forklift, prior to being moved to the third buffer at the Rear Wheel station when this buffer is empty.

Figure 6 **Photograph of knuckles - finished goods buffer**

Source: for this research, Chappell 2011

Figure 7 is a CAD drawing of the section of the plant layout showing the Rear Wheel End 20 (RWE 20), production cell and the RWE 10 two press cell layout. Parts produced in the Press cell feed RWE 20 which feeds the main production line. The diagram does not show all of the buffers.

Figure 7 **CAD drawing of ZF Rear Wheel End Assembly Cell**



Source: ZF Manufacturing Engineering 2011

Key Findings

In response to the research questions, the research findings are as follows:

1. **Is the current production setup at ZF optimal?**

   The research shows that the current production setup is not optimal and that there are changes that should be made to optimise the layout.

2. **What is the impact to the process due to changes in demand?**

   The research shows that the reduction of demand has led to a slow down of the production line, an increase in buffers in the processes and the introduction of many staging areas to hold these buffers.

3. **How does the plant layout contribute to waste in operations?**

   The layout of the plant, which would have been optimal at 180,000 units over three production shifts, contributes to waste due to it not having been adapted to the current situation (65,000 vehicles and 2 shifts). The research identified waste in stock and in excess movement in many areas.

4. **Using one process as a research base, what can be done to improve the situation, if proven that there is a need for change?**

   The research identified areas for improvement, suggestions for changed layout of the processes and overall changes that should be made.

In response to the research questions, the research highlighted that the main issues in the process were with idle time for the press operator and the process operator at the rear end sub assembly cell; the large finished goods buffers; and component and sub-assembly buffers throughout the process. The value stream maps highlighted waste in the system and higher than necessary inventory. While buffers remove the impact of the bullwhip effect, they are not in line with the company's JIS goals. The bullwhip effect is a supply chain dynamic whereby relatively small changes in demand have a greater impact as they move up the supply chain, resulting in increased stock overall in the system (Slack et al. 2009, p. 232). While ZF is a JIS plant, the individual processes that support the main, continuous flow

production line are set up as JIT processes. This is due to there being no electronic signal or trigger between internal work cells.
The research supports the premise that production lines should be constantly rebalanced with changes in customer Takt time and demand volume mix. Personnel that work in the particular area should be included in any changes and should be asked for their input into changes that are being made. TPS / ZFPS philosophies are based on the premise of the people directly involved in the process being an integral part of the improvement process (Liker 2004).

In line with the lean synchronisation aim of meeting demand instantly with perfect quality and no waste (Slack et al. 2009, p.352), the suggested solution from the research is detailed in the Recommendation section.

Recommendations and conclusions

The recommendation for ZF Australia is to make substantial changes to the process layout in the RWE production area. The process layout changes will remove the entire separate knuckle bush pressing cell as a standalone process. This should be incorporated with the RWE assembly cell so that the existing RWE assembly operator will press in the bushes and assemble the other components before sending the parts on to the next stage in the cell. The change will eliminate three sets of buffers, free up production floor space, reduce overall inventory and reduce headcount by one process operator. This is visualised comparing the current state value stream map with the future state value stream map. The improvement will remove 288 pieces of finished knuckle assemblies out of the production area, equivalent to more than a full shift's requirement and regain six cubic metres of space. In addition, the access by forklift to these spaces frees up an additional ten to twenty square metres of plant space.

It is further recommended that the management team of ZF Australia view the ZFPS analysis and follow up on already identified areas for improvement. Furthermore, a similar process to this research in other areas of the plant will uncover additional improvements to reduce waste and improve productivity and profitability. The adoption of a leagile approach throughout the supply chain, rather than a pure lean process, is further recommended due to the demand uncertainty of the OEM (Slack et al. 2009, p.372).

Conclusion

In conclusion, through the detailed analysis of one of the processes in the production line, the research has shown that it is possible to address five of the seven types of waste as identified in TPS and subsequently the internal ZFPS at ZF Australia.

These are:

- Transport—moving of parts not required to be processed
- Inventory—work in progress and finished goods
- Motion—of production operators moving between cells and in obtaining components and of logistics operators feeding each area with components
- Waiting—waiting for the next production process
- Overproduction—producing for a buffer

This was a worthwhile exercise not only in being able to test what has been studied but in being able to apply this knowledge in a live situation. In addition, being able to articulate and share valid improvements that will drive profitability was an extremely rewarding experience. Of most interest from the research is the fact that a highly automated plant with world class facilities, processes and benchmark operating standards can have so much waste in the system that can be removed fairly easily at a small initial cost.

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Appendix 1 **Example of Questions used in Interview with Operators**

	<u>Questionnaire for Case Research – ZF Rear Wheel End Assembly</u>
	<u>Operator and Plant Personnel</u>
Name	
Position	
Date	
Qu. 1	**Do you consent to being interviewed for a Case study Research into the Production processes at ZF Adelaide? Do you consent to your name being used in the research survey?**
Response:	
Qu. 2	**How long have you worked on this process and have you been trained as an operator of this process?**
Response:	
Qu. 3	**What is the sequence of the manufacturing process at RWE 10?**
Response:	
Qu. 4	**How much idle time is there in the current process?**
Response:	
Qu. 5	**How much time per shift / day / week do you have to wait for Logistics to provide raw material or to remove finished goods buffers before you are able to produce again?**
Response:	
Qu. 6	**Would you prefer idle time or to be utilised more of the time during each shift?**
Response:	
Qu. 7	**How do you feel idle time could be reduced?**
Response:	

Qu. 8	**What do you think the buffer should be between RWE 10 & RWE 20 of pressed knuckle assemblies?**
Response:	
Qu. 9	**Following on from your ZFPS & Cert 3 Lean manufacturing training, Can you see waste in the system and can you give me some examples?**
Response:	
Qu. 10	**How do you feel the production process at RWE 10 could be better optimised?**
Response:	
Qu. 11	**Why, in your opinion, is this a standalone production station and not part of RWE 20?**
Response:	
Qu. 12	**Do you feel that there is excessive forklift movement in the production area at RWE 10 & RWE 20? And in the rest of the plant?**
Response:	

Source: developed by Neil Chappell for this research 2011