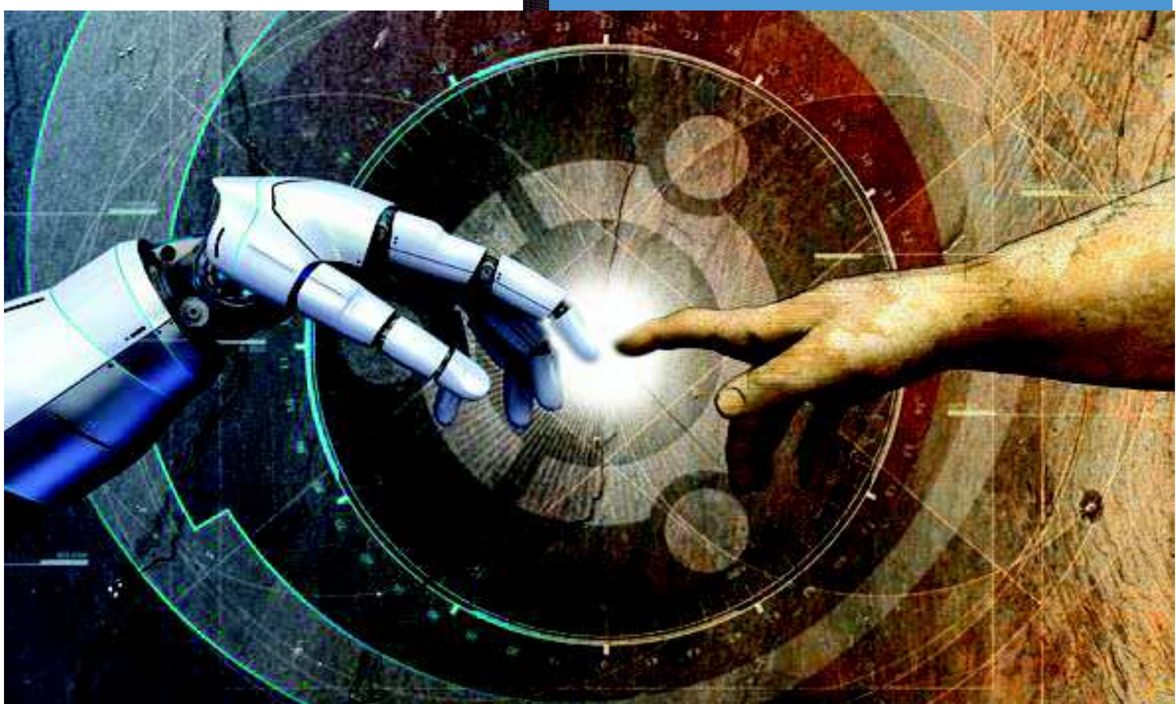
2018

Considering the Manufacturing System within a DFA Assessment



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Introduction

Making correct cost decisions in the infancy phases of product development programs is critical for successful and profitable products. Advanced manufacturing is one functional discipline within concurrent engineering that focuses on using simulations to understand manufacturing costs. The Design for Manufacture and Assembly (DFMA) software from Boothroyd Dewhurst is one of the tools used to estimate manufacturing assembly time and thus the cost. If it is concluded that the estimates may not meet the targets, there is a strong risk that changes to scope, schedule or resources, will ultimately reduce the value proposition of the business case.

Some companies put their best foot forward by using Design for Assembly (DFA), one of the DFMA modules. What can be an oversight with using the DFA tool is the interactions of Man and Machine and how these are reviewed in Lean Methodology, especially targeting and eliminating wait time. This Paper explores the need to evaluate Man and Machine interactions and the wastes ([i]) these create in a manufacturing system. Moreover, understanding better the specialist assembly equipment is also explored. The objective is to gain a greater understanding of the impact of specialized assembly equipment on the overall assembly time. This data is used for both Product Portfolio planning and eventual development of the assembly process.

Identifying the Problem

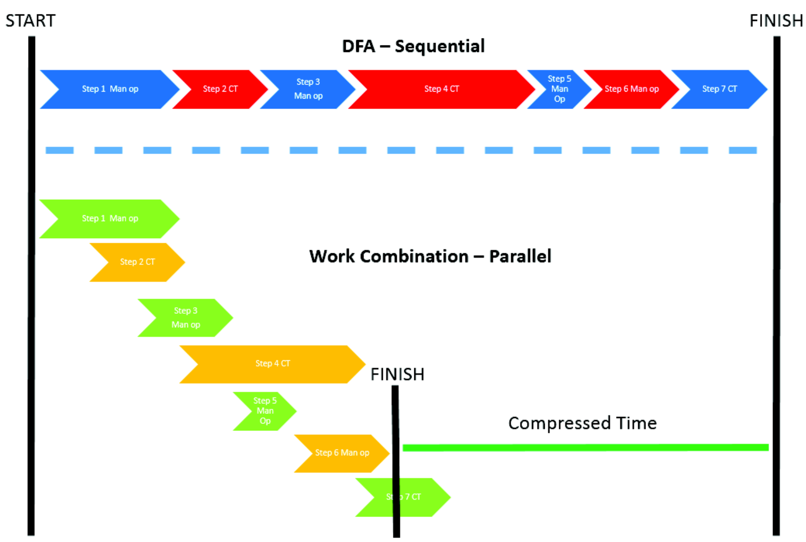

FIG A DFA Sequential task Vs Work Combination Parallel total

A New Product Development team at Kohler was tasked to provide assembly time estimates of a product that was approaching a stable design concept. As the detailed design progressed, design changes to meet performance forced the Advanced Manufacturing team to reassess the original process plan. The team used the DFA tool to evaluate the revised cost and assembly times. The Advanced Manufacturing group discovered that the DFA tool was not taking into consideration the operator activity that happens during the cycle times of the specialized assembly machines. All the operations were added up sequentially to provide the total assembly time within the DFA tool.

This however, is not reflective of the actual time, as when an operator loads a machine and starts the cycle they do not stand and wait for the cycle to complete prior to moving to the next operation. The objective is for the operator to work in parallel to the machine cycle time (CT[ii]) reducing wait time and converting Non-Value Added (NVA) time to Value Add (VA) or Necessary Non Value Add (NNVA) time. This results in a shorter elapsed time as shown in Fig A.

The NPD team provided output from the DFA tool to management, which was later found to be an overestimate of assembly time that put the program at risk of not proceeding. The primary factor that was over looked was the wait time. The Lean Methodology that uses a Standard Work Combination ([iii]) table tool wasn't used to identify manufacturing wastes and identify Man and Machine interactions. The key consideration that was originally over looked was the wait time and parallel activity. The DFA tool was lacking the capability to identify these overlapping factors. There is a need to reflect these in the manufacturing system for the quotes used in both portfolio and project execution planning.

Summary of the Solution

This paper describes how the Advanced Manufacturing group within Kohler Global Faucets created tools to supplement the DFA results to ensure that Man and Machine was considered in the assembly process for new product development projects. It reconnoiters the need to create bespoke operations libraries for Ultrasonic Welding, Heat Staking, specialized product testing and inspection. The identification of Non-Value Add (NVA) activity to support the summation of realistic assembly times used in a Standard Work Combination is also presented.

Analysis

This effort started when Kohler was in the process of designing a new valve that required development of an innovative manufacturing system. The Advanced Manufacturing group was handed the responsibility to design a line to utilize two to three line operatives. The assembly techniques needed to include, Heat Staking and Ultrasonic Welding. Adding to the challenge were some geometric tolerances resulting in very stringent inspection processes. Due to the complexity of manufacturing, many process engineering iterations were made over several months.

The very first assembly time estimate was the result of a Production Preparation Process event (3P[iv]). The team cobbled together a physical simulation (1:1 scale) which was used to obtain an initial time estimate with work measurement. The DFA tool was also used monthly, conducted during the event for reassurance and direction of product redesigns (gauge design changes using the DFA index). This was without consideration for Cycle Time (CT) of the machines and parallel operations. It was ascertained that there was a 41% increase from the 3P simulation times to that of the DFA analysis results. At this point the project was not looking profitable. The issue with Man and Machine finally became apparent the Work Combination tool was used. Dwell time and machine cycles were not being accounted for. The team moved forward to use the Work Combination tool with the DFA data. This resulted in a 27% decrease from the previous analysis. Fig B shows the compression and overlapping activities. Blue indicates operator's intervention and the dashed line is the machine cycle. Notice that the total time for the combination of parallel activities is significantly less than the total time for the sequential activities in the DFA analysis represented by the vertical red line.

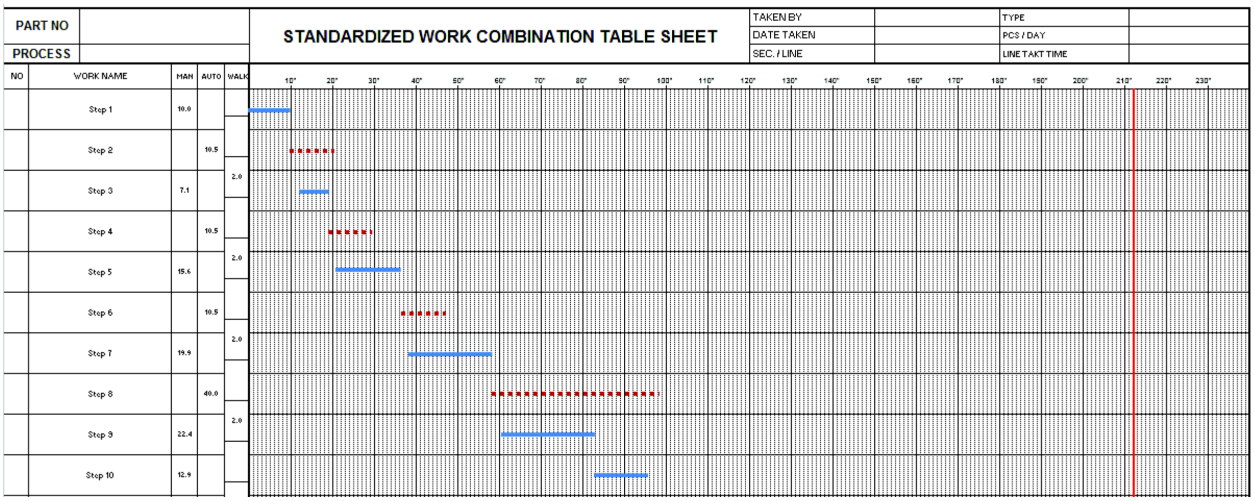

Fig B - Work Combination table

Improvement

The first step to creating a solution was to ensure each bespoke operations entered into the DFA tool had considered all the possible variables that would affect the final time calculation, including operation for Ultrasonic Welding, Heat Staking and Advanced Air Testing. Without these considerations, there is a risk of underestimating the time. Table A displays the default time from the Boothroyd Dewhurst (BD) DFA software compared to the results using the new custom Kohler Operations that were developed. Ultrasonic Welding for the Kohler assemblies had a variance as high as 63%, and a variance of 42% for Heat Staking.

Operation	Standard DFA BD	Variance %
Ultrasonic Welding	10 Sec	4.12%
Heat Staking	9 Sec	3%

Table A Boothroyd Dewhurst default Vs Custom Operation (Times provided are for example only)

The product that was being developed and the case study for this paper would sit on the Puttick Grid (v) in the range of lower left corner of fashion/spares to upper right corner of consumer durables as shown in FIG C. Given its position in the Puttick Grid it can be appreciated that a few seconds variance with each operation adds up to a very large amount considering the volumes associated with its product position. The DFMA software by BD allows for customization by the user, therefore, the first operation that was developed for the Kohler DFA library was Ultrasonic Welding.

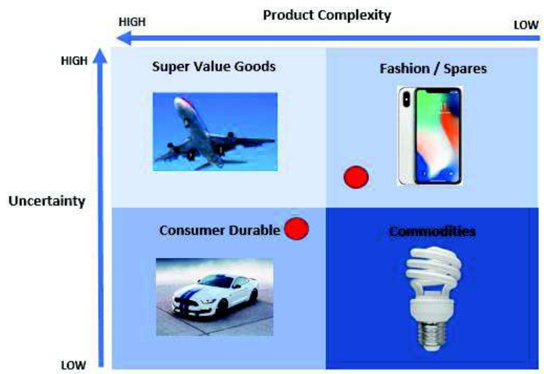

FIG C Puttick Grid

Modifications to the libraries are as follows:

Ultrasonic Welding

The part 'load' and 'unload' times are included and summated to a NVA time. The Horn distance and speed can affect the time of the operation that aligns to the machine manufactures specification table. The further the stroke the longer the operation. The hold time can vary depending on how long the energy is to be sustained during the weld. Time is defined with trial, error and experience to achieve the optimum weld.

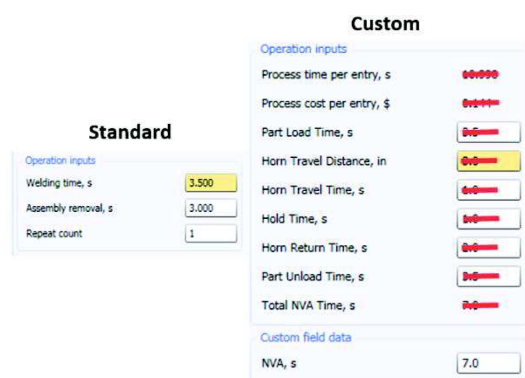

FIG D Standard Vs Kohler Custom Ultra-sonic welding Parameters

Heat Staking

Staking has similar parameters to that of Ultrasonic welding. Horn travel, hold, return time would be replaced with Ramp, Soak and Punch. The first is the 'Ramp'. This is the time needed to get the InfraRed node to temperature. 'Soak' the time the heat energy is applied to the sprue and lastly the 'punch'. This is the time the forming die is in contact with the molten material as shown in FIG E.

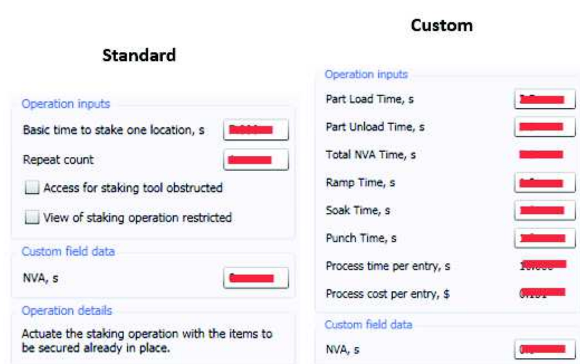

FIG E Standard Vs Kohler Heat Staking Custom Parameters

Inspection

Two additional inspection operations were added to the library. First there is an internal component requiring Run Out inspection. Second is a Quality control requirement with assembly height. A coordinate measurement machine was used line side for assembly height measurements. Inspection activities have many variables that effect time that need to be accounted for within the DFA analysis as shown in FIG F.

FIG F Kohler Custom Parameters for Assembly Height & Run out

Air testing

Valving testing can have a variety of air tests all consisting of different testing cycle times. In this instance, 'Leak' testing is done to ensure all welds are functional. 'Cross Flow' testing is to ensure all internal seals are operating correctly and a dynamic test to verify the product is performing to the required operational standards. For this operation, the user can select the test from a drop-down menu as shown in FIG G.

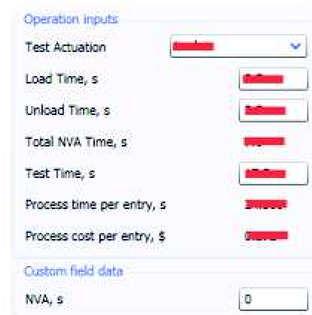

FIG G Kohler Air testing Parameters

The custom Kohler operations provides a process that is more refined and reflective of actual assembly times of the machines being used within the manufacturing system. These operations provide a more accurate foundation for a DFA analysis. The next steps are to enter the DFA data into a Standard Work Combination. The table shows the importance of doing this when looking to establish a total assembly time when Man and Machine are a part of the manufacturing system. FIG H shown below compares the total assembly times of: -

1) DFA with Kohler custom operations and Work combination
2) Kohler 3P physical simulation time
3) DFA using the Standard operations

The total variance from the DFA (on the right) to the Kohler Custom operations with the use of a standard Work combination is 51%

The concern with drawing a conclusion with data in figure H is that there is no actual time to compare against. The 3P was a physical simulation which is not a true representation of the process. Due to this the same process was applied to a similar product that was coming to market launch where actual labor time (time study) could be compared. FIG I below shows the comparison and only strengthens the validity to use the Standard work combination tool.

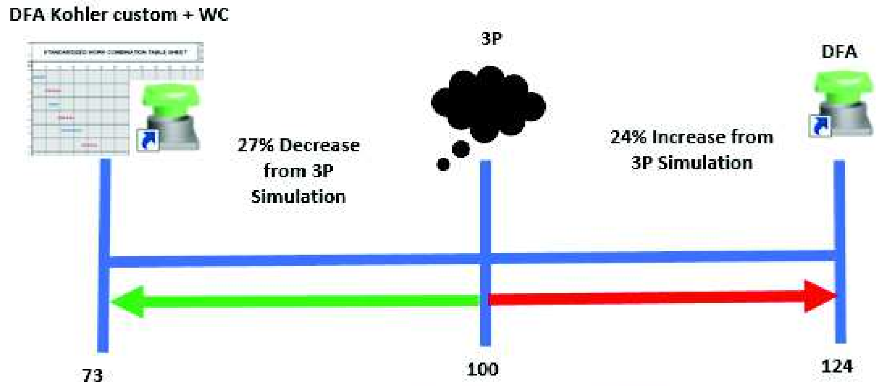

FIG H Time Comparisons of 3 methods used
(Times are normalized to 100)

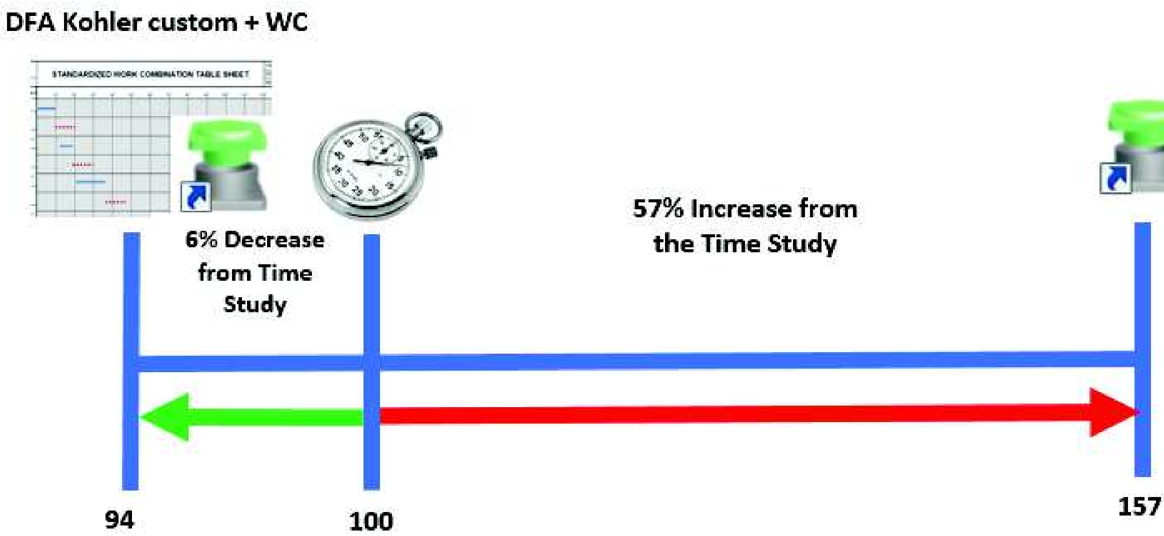

FIG I Time Comparisons of 3 methods used
(Times are normalized to 100)

Method

A simple working practice was created for DFA users to determine the man and machine interactions and the effect these interactions have to the assembly time. The method consisted of two templates which were designed to work with each other (BDI DFA with Excel template Work Combination).

The output of the data from the DFA needs to align to the Excel template so that a cut and paste of the data set is aligned. To achieve this the ‘Tabular reports generator’ function was used. This is located within the ‘results’ tab of the BD software. Ensure to select all the data fields that are configured to match the excel data entry page. The new customized report was titled Work Combination for this example shown in FIG J.

FIG J New Custom Work Combination report

Once the DFA is complete the user can now generate a report using the new Work Combination configuration. The report can be exported to .xls format to be pasted into the supporting excel Work combination document.

The Excel macro template was created to reduce user errors with transposing information from one file to another. Creating a raw data entry page with in the excel template allows for a straight forward paste of data from the DFA. Simple Marcos and formulas within the spread sheet populated the Standard Work Table. The tool allows the text data from the DFA to import to the Process Step Columns. Manual and Auto time can be calculated from the DFA data. Identifying what parts have a classification of Minimum Part Criteria[vi] is a good starting point to base any logic for time calculations. Creating a simple Excel ‘IF’ statement will allow you to calculate parts with Manual time. The remaining line items in the DFA report will most likely be operations which may have some automatic time associated. In these situations, creating a bespoke operations library with NVA summation as (explained earlier) will help calculate the division of what is manual to automatic time. It is expected the walk time to be added manually within the Work Combination as the final step. Once the Standard Work Combination template is created it is now time to customize the DFA data output to align to the excel Work Combination tool. To do this ‘custom user fields’ may need to be added. This feature can be found in the ‘analysis tab’. Any bespoke calculation you included in the modified operation library will need to be included in a report. For this instance, NVA time was needed.

A simple click of the Marcos button now populates the Work Combination Gantt and provides a cycle time line that is representative of Man and Machine interaction and a more accurate time than if the DFA report would have provided with sequentially added time.

THE BOLD LOOK OF KOHLER

Summary

The need to provide realistic estimates with assembly times and costs at the planning and contractual stage of a new product development project is critical. Under estimate and your business may make a decision that will have the risk of being non-profitable. In contrast if you overestimate, there is the risk of missed opportunities. The use of the DFA tool is a great place to start planning. This said, there is a need to tailor the DFA tool to custom business processes and manufacturing systems. The example within this paper highlights the unique assembly processes, inspection machinery and the interaction of Man and Machine. Relying solely on the DFA study without factoring the full manufacturing system could be damaging to the business planning.

Understanding the interaction of a Man and Machine manufacturing system and researching the machinery in detail, provides a more refined estimate for the project in question. In this example, it reduced the time estimate as much as 51%. It can be appreciated that the 51% estimate is a big deal.

In closing there are great benefits with considering the manufacturing system when completing the DFA. The lesson learned was to consider the interaction with Man and Machine, identifying NVA and how it will affect manufacturing. Also, how the machines operate and what factors would increase or decrease the time from the default DFA.

Are you and your teams missing opportunities with new product launches or paying the price at launch for product costs and cycle times not hitting the targets?

FIG K Kohler DFA Standard work combination Gantt

Appendixes

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[i] Seven Lean Wastes

The 7 Wastes of Lean Manufacturing

Waiting

Waiting is perhaps the most obvious of the 7 wastes of lean manufacturing. It is easily identifiable as lost time due to poor flow: parts shortages, bottlenecks, and equipment breakdowns. In an office based environment, this may take the form of slow software loading times or waiting for an important phone call. This is also frustrating for the employees involved, which can lead to reduced morale.

Over Production

Over production is the most important of the 7 types of waste. It is building more of a product than the customer ordered or wanted. Remembering that waste is anything for which the customer is not willing to pay, it is easy to see why over production is a waste. However over production actually drives all of the other six types of waste as well. The excess product now has to be stored somewhere which means excess motion, transportation and inventory. Also, over production means that if a reject is found, there will be more units that need to be reworked.

Rejects

Parts that do not comply with the specifications of the customer lead to rework. Worse still they can lead to scrap and the necessary production of new parts. Usually, rejects have to be sent back down the production line again to be put right. This consumes valuable production time. Sometimes a separate rework area is required, which increases labour and duplicates tooling.

Excess Motion

This is wasted movement that is made while working. It could take the form of having to walk to another area to collect a tool, part or document. It also covers searching for things in a messy environment. A classic example is sorting through piles of paperwork to find the one form required at that moment to complete the job.

Over Processing

This is work that adds no value for the customer or business. This usually takes the form of over engineering a product: unnecessary features that the customer does not use, but that increase the cost to the business. This could be maintaining paint finish or other tolerances, more tightly than is required by the customer. Another example is building a product that will last for five years when the customer is going to replace it after two.

Excess Inventory

Excess material, work in process or finished goods. Excess inventory represents cash tied up in the form of material, which is difficult to turn into cash quickly. Inventory also takes up space. It has to be managed, stored and can become obsolete leading to scrap. The quality of inventory can deteriorate over a period of time, especially perishable items such as food or rubber seals.

Transportation

Unlike excess motion which is wasted movement of people, transportation is excess motion of work in process. This can be at the process level or the value stream level. At the process level, excess transportation can be having machines too far apart so that parts need to be moved on a fork lift truck. At the value stream level, excess transport can be moving finished parts or components between facilities and not consolidating the transport.

[ii] **Cycle time** is the total time from the beginning to the end of your process, as defined by you and your customer. Cycle time includes process time, during which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spent waiting to take the next action.

[iii] **Standardized Work Combination Sheet**. The main data relevant for the Combination Sheet is the way different parts of the working process interact with each other, and the timing needed between the various steps involved. As the name of the sheet implies, it shows how the different timing values combine, including the manual work time, walk time, as well as machine processing time.

[iv] **3P - Production Preparation Process** is often referred to as "design for manufacturability." Starting with a clean development slate, 3P rapidly creates and validates potential production and process designs that require the least time, material, and capital resources. 3P typically results in products that are easier to manufacture, have built-in quality, and have less complexity.

3P designs processes that flow better and utilize simple, right-sized equipment that better meet production needs. Organizations engaging in 3P select the best product or process design among multiple alternatives developed from lean techniques.

[v] **Puttick Grid**

Super Value Goods

Highly complex products, specific requirements for which are highly uncertain. The lifecycle of these products is generally long, with up grading and re fitting common. Industries which best fit within this category are aerospace, defense, heavy electrical equipment and railway equipment. Differentiation is based on fitness for purpose and service support.

Fashion / Spares etc.
These products are categorised by suddenly high demand, rapid depreciation and high rates of obsolescence, or the products
are suddenly needed and demand is immediately fulfilled. Industry sectors which fit within this category are food and drink, cosmetics, mobile phones and emergency calls on contractors such as builders, plumbers and electricians. Emotional appeal and time to market within a limited window of opportunity are key methods of differentiating fashion or spares products.

Consumer Durables
For consumer durables, there is a medium-term lifecycle with a strong focus on a second hand market. Industries such as automotive, white goods and machine tools fit within this category. Value for money and availability are important differentiators for the consumer durables products.

Commodities
These products are generally consumables which can be recycled such as simple components, paper, primary metals and glass. Price is the key differentiator of commodity products.

[vi] **Minimum Part Criteria** - Items that have not been identified as fasteners or connectors are evaluated against the Minimum part criteria to determine if they are theoretically necessary or candidates for elimination. This evaluation should take place as you imagine the product being assembled.