TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Mechanical and Industrial Engineering

# NEW PRODUCT IMPLEMENTATION PROCESS IMPROVEMENT IN PKC GROUP

## UUE TOOTE JUURUTUSPROTSESSI PARENDAMINE ETTEVÕTTE PKC GROUP NÄITEL

MASTER THESIS

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Tallinn 2022

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# NEW PRODUCT IMPLEMENTATION PROCESS IMPROVEMENT IN PKC GROUP

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**Thesis topic**:

*New Product Implementation Process Improvement in PKC Group*

Uue toote juurutusprotsessi parendamine ettevõtte PKC Group näitel

**Thesis main objectives**:

1. Company and production overview
2. Strategic Future Truck Program overview
3. Input data evaluation and initial projections for needed resources
4. Validating the planned processes and capacity
5. Benefits and improvements done during the product launch

**Thesis tasks and time schedule:**

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| 3. | Analysing the implementation process | 21.04 |
| 4. | Summary of observations and proposals for further improvement | 08.05 |

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# PREFACE

The topic and subject of the thesis was formulated by the author with support and advise from the supervisor, Professor Kristo Karjust. Company PKC Group provided the main input data and the results and analyse done during thesis formulation has been provided back to the company.

I would thank my colleagues in PKC Group who supported me with all necessary input and helped me with conducting the needed analyse. Also, I would like to thank my supervisor Mr. Kristo Karjust for his continuous support and my family to provide me the necessary time to complete the thesis.

This thesis investigates a large-scale production launch of wiring harness manufacturing, analyses the procedures needed for launching a high-mix high-volume labour intense production operation. Equipment and labour for a case project are calculated together with establishing necessary planning for the product launch. Based on the observations, improvements to project management and production launch planning methodology are made.

Keywords: New product Implementation, High-mix high-volume, Wiring harness manufacturing, Tailor-made products, Ramp-up plan, Project management, Master’s Thesis

# LIST OF ABBREVATIONS AND SYMBOLS

| | |
|---|---|
| AE | Advanced Engineering |
| AG | *Aktiengesellshaft* (joint-stock company) |
| APQP | Advanced Production Quality Planning |
| BOL | Bill of Labour |
| BOM | Bill of Material |
| CAD | Computer Aided Design |
| CAPEX | Capital Expenditure |
| CEO | Chief Executive Officer |
| CT | Cycle Time |
| EBITDA | Earnings Before Interest, Taxes, Depreciation, and Amortization |
| EDI | Electric Data Interface |
| EDS | Electrical Distribution Systems |
| EU&SA | Europe and South America |
| FY | Fiscal Year |
| FOT | First Off Tool |
| HR | Human Resources |
| IATF | International Automotive Task Force |
| IT | Information Technology |
| JIS | Just-in-Sequence |
| JIT | Just-in-Time |
| KSK | *Kundenspezifischer Kabelbaum* (Customer Specific Wiring Harness) |
| LAD | Line Assembly Design |
| ME | Manufacturing Engineering |
| Mfg. | Manufacturing |
| Min. | Minutes |
| MRP | Manufacturing Resource Planning |
| NCR | Non-Conformity Request |
| NPI | New Product Implementation |
| OEM | Original Equipment Manufacturer |
| PAT | Profit After Tax |
| Pcs. | Pieces |
| PPAP | Production Part Approval Process |
| PV | Process Validation |
| PVC | Polyvinyl Chloride |
| QMS | Quality Management System |
| RAS | Requisition Approval System |

| | |
|---|---|
| RASIC | Responsible, Accountable, Support, Information, Consultation |
| RFQ | Request for Quotation |
| SFTP | Strategic Future Truck Program |
| SOP | Start of Production |
| WH | Wiring Harness |
| XVK | *X Variant Kabelbaum* (X variant wiring harness) |

# 1. INTRODUCTION

The aims of thesis were to prepare and carry out a significant scale product launch – SFTP wiring harnesses into serial production in PKC Group, validate the initial projections and evaluate the outcomes with proposals how to improve the new product introduction process for upcoming product launches.

New Product introduction (NPI) is the process where a company creates an idea and carries it through to commercialization. The emphasize is on introduction process, rather than the new product development, because NPI looks at the product from the viewpoint of manufacturing, ensuring that the production ramps up smoothly and rapidly [1].

The first introductory part of the thesis gives an overview about PKC Group and company's procedures for new product implementation. In the main part of thesis following tasks were completed:

1. **Overview of Strategic Future Truck program wiring harness manufacturing launch together with applicable improvements to launch from previous launch experience.** This part of thesis gives overview of new launch project which is used as case study for improving the launch process. Lessons learned from previous product launches are described which are intended to implement for the product launch under observation.
2. **Analysing the product data, defining the production concepts, and defining necessary resources to carry out the product launch.** Using the product data provided by the customer and combining it with known data about work times and processes, production concept for each product is defined together with direct labour, equipment and floorspace calculation.
3. **Evaluating the product launch with implemented improvements and formulating updates for the PKC Group procedures using SFTP launch as a benchmark.** Here the actual situation of product launch is evaluated using process validation build audits and other observations of product implementation process as evidence. Based on the changes to launch process implemented during the SFTP launch, PKC Groups Quality Management System is updated and the planned ramp-up duration is shortened for selected product groups which provides direct financial benefit for the company.

# 2. NEW PRODUCT IMPLEMENTATION PROCESS OVERVIEW

Typical manufacturing processes are about the ongoing production of existing offerings; NPI "introduces" new products into the manufacturing process. NPI emphasizes the introduction to manufacturing aspects of New Product Development, ensuring that the product ramps production smoothly and rapidly [1].

While nearly every company develops new products or services, the new product introduction process differs substantially from one company to another. Variables include the industry, the product type, whether the products are an incremental improvement or a breakthrough innovation, and the degree to which you focus on product portfolio management [1].

Although cross functional processes differ depending on these factors, an accepted approach for at least three decades puts a new product idea through a series of steps. At the end of each of the six steps, the Senior Management team makes an up-or-down decision in a formal review (often called a "gate"). A typical NPI approach has six steps with five gates [1]:

Step 1: Ideation;
Step 2: Product Definition;
Step 3: Prototyping;
Step 4: Detailed Design;
Step 5: Pre-Production (Validation/Testing);
Step 6: Manufacturing.

In case of companies which offer subcontracting services for manufacturing products which are designed by their customers, the NPI process focuses on process design, planning and manufacturing steps. Process design step consists various pre-build events, starting with design validation builds, then continue with process validation builds and run-at-rate builds. The manufacturing step is split to ramp-up phase with defined ramp-up curve for reaching target output. After the intended volumes are achieved, the focus shifts to efficiency improvements to bring the productivity and quality to targeted levels.

Figure 2.1 presents typical new product implementation steps from the initial idea until launch and manufacturing.

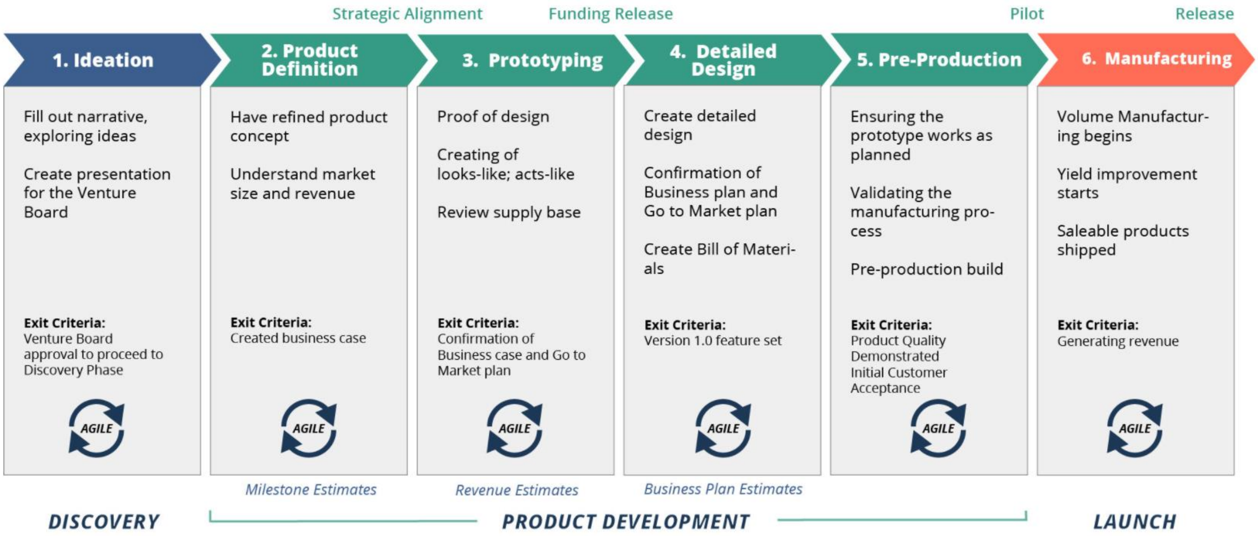


Figure 2.1 New Product Implementation Process steps [1]

# 3. COMPANY AND BUSINESS ENVIRONMENT

## 3.1 History of PKC Group

Beginning of the company is dated to year 1969 when Nokia subsidiary Pohjolan Kaapeli electrical distribution systems factory was founded in Kempele, Finland. Company started with 40 employees, producing wiring harnesses for Nokia. The company grew out from Nokia's inhouse cable production unit because of market opportunity created by Valmet Oy which started to produce Saab passenger cars in 1966 in Finland and was looking for local manufacturer for electrical distribution systems – mainly wiring harnesses. Company got significant increase in production volumes in beginning of 1980's when contract was signed with Volvo AB to supply wiring systems for Volvo passenger cars. At 1981 Talbot, SISU, Volvo and several bus manufacturers belonged to customer portfolio. At 1991 the company employed 700 workers and produced electrical distribution systems for Saab-Automobile, Saab-Valmet, Scania, Volvo, Nokia Mobile Phones and Nokia ICL Data. [2]

Subcontracting in Estonia and Russia began during 1990–1992. 1997 PK Cables was listed in Helsinki Stock Exchange, in 1998 was opened factory in Brazil, supplying wiring harness for Volvo Trucks and Scania Brazil subsidiaries. In 1998 PKC Cables acquired electronics business unit. Rebranding to use "PKC GROUP" name was done on year 2000. Subcontractors in Russia and Estonia were acquired during years 2002 and 2003. In 2005 company started operations in China to provide wiring harness products for local commercial vehicle manufacturers such as JAC, Foton and Sinotruk. In 2008 PKC Group acquired wiring harness production unit from MAN Trucks and expanded operations to Poland. In the autumn of 2011, PKC Group signed an agreement for the purchase of the AEES companies from funds controlled by Platinum Equity. AEES was one of the leading North American wiring harness manufacturers for heavy and medium duty trucks, and it also had a significant share in light vehicle wiring harnesses. Clients of AEES included Daimler Trucks North America, Navistar, and PACCAR. After the acquisition, PKC Group employed around 18 000 persons worldwide and become one of global leading wiring harness manufacturers for commercial vehicles market. [3]

During 2010's PKC Group growth continued via several acquisitions – 2011 SEGU in Germany, 2014 former subcontractor in Lithuania, 2019 Bombardier's UK rolling stock electrical components business and several others. In 2013 new factory was opened in Serbia, in 2020 in United Arab Emirates. Until 2016 PKC Group had manufacturing units in Estonia in two locations – Keila and Haapsalu – with total 2500 employees at peak.

The operations were transferred to lower cost production units during 2015 and 2016. [4]

In 2017 PKC Group was acquired by Motherson Sumi Systems Limited (MSSL). Since 2017 regional headquarter of PKC Group Europe and South America operations has been in Tallinn, Estonia. Subsidiary PKC Eesti AS is a Business Service Centre and focuses on high value-added activities, providing various services to its customers and manufacturing locations. PKC Groups Regional Sales & Engineering, NPI & Project Management, Sourcing & SCM, Finance, HR and IT functions are housing about 80 employees in the Tallinn office. [5]

Motherson Sumi Systems Limited (MSSL) is the flagship company of the Motherson Group. It has been listed at the Indian stock exchange since 1993. The company is a specialised full-system solutions provider and caters to a diverse range of customers in the automotive and other industries across Asia, Europe, North America, South America, Australia, and Africa. MSSL has growing presence in wiring harnesses, rear-view mirrors, cockpits, bumpers, interior trim as well as a broad range of other polymer, elastomer and metal-based parts and systems. [6]

MSSL is ranked 22nd in the list of the world's largest automotive component suppliers. The company operates through nine business divisions, which continue to grow stronger and become more diverse. These divisions are Wiring Harness, Vision Systems, Modules & Polymer Products, Metal Products, Technology & Software, Retail & Services, Aerospace, Logistics, and Health & Medical Devices. In 2019-20, the group recorded a turnover of USD 11.2 billion. [7]

## 3.2 Products overview

Electrical distribution Systems (EDS), also known simply as wiring harnesses, are used for power supply and data transfer in heavy trucks, light vehicles, buses, and recreational vehicles as well as in construction, forestry, and agricultural equipment. An EDS manufacturing company such as PKC Group is usually Tier1 supplier in automotive industry, so end customers are OEM's (original equipment manufacturers). PKC Group produces build-to-print products, means that product design and component selection is mostly done by the customer. A wiring harness is a set of insulated wires, plugs, sockets, relays, fuses, and other components. First main function of EDS is supply various sub-systems in vehicle with power using stranded and insulated copper or aluminium wires. Second function is data transfer between vehicle's subsystems using

CAN-protocol (Controller Area Network). Example of main EDS components in a commercial vehicle are shown on figure 3.1 and 3.2. Wiring harness manufacturing is considered as labour-heavy and mostly manual process; however, parts of the processes can be done by using automatization and machinery with several flexibility requirements. One of the characteristics of this service is high variation of different product options. Example of a complex wiring harness is shown on graphics section.

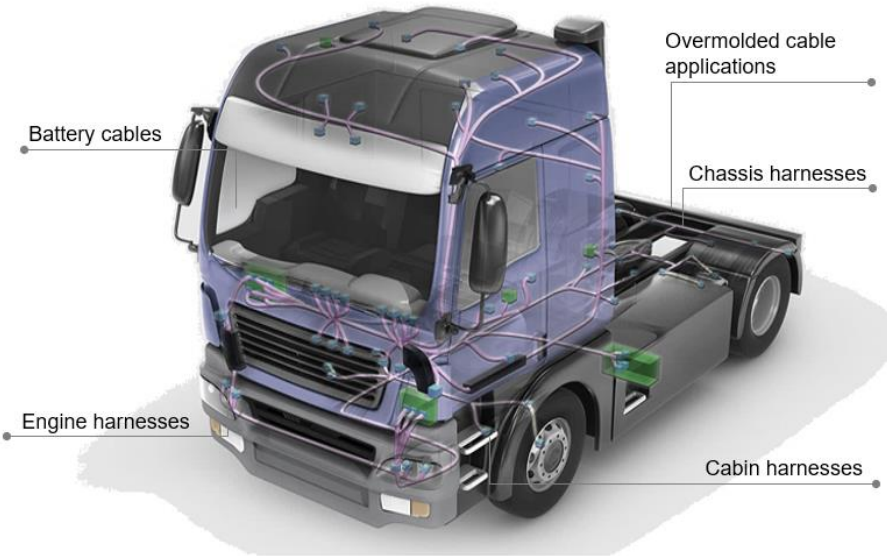


Figure 3.1 Overview of commercial vehicle EDS [9]

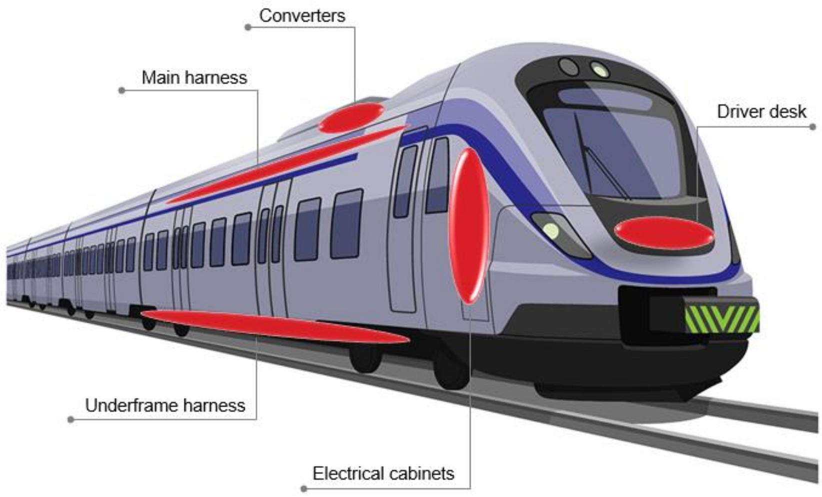


Figure 3.2 Overview of rolling stock EDS [9]

## 3.3 PKC Group services and customer base

PKC Group is a global partner engaged in designing, manufacturing, and integrating electrical distribution systems, electronics, and related architecture components for the commercial vehicle industry, rolling stock manufacturers and other selected segments. In addition, PKC designs and manufactures electrical cabinets, power packs and electrical distribution systems for leading rolling stock manufacturers. [7] Main global markets are Europe, North America, Brazil, and China. PKG Group customer base covers majority of large OEM's such as ACGO, Alstom, Bombardier, Dongfeng, Daimler Trucks, Foton, JAC, John Deere, MAN, Navistar, PACCAR, Scania, Siemens, and Volvo. [9]

EDS design and component selection is usually done by the end customer, this makes PKC a build-to-print manufacturing service provider. Build-to-print contract requires the contractor to build a product according to the exact technical specifications given by the customer. The design specifications are explicit and are often coupled with performance specifications. Therefore, the contractor hardly has any discretion in deciding how to perform.[11] However, customers acknowledge the supplier's expertise in the given field of industry and often expects product change proposals from suppliers which allows to reduce the costs. Other fields of expertise are needed, such as rapid engineering change management, ability to handle multiple variances of similar product, delivering just-in-time, delivering just-in-sequence, after-market parts production and managing supply chain which consists of more than three hundred suppliers and thousands of different components.

The below Table 3.1 shows the production of commercial vehicles in the main global markets during the last 3 financial years. A financial year in PKC Group is starting 1st April and ends 31st of March

Table 3.1 Commercial vehicle production in main global markets [7]

| **Produced trucks (pcs.)** | **FY 2018** | **FY 2019** | **FY 2020** |
|---|---|---|---|
| **North America** | | | |
| Heavy Duty Trucks | 278 398 | 340 889 | 315 499 |
| Medium Duty Trucks | 261 178 | 285 568 | 276 264 |
| Light Vehicles (Pick-up & SUV | 10 331 018 | 10 685 703 | 10 580 885 |
| **Europe** | | | |
| Heavy Duty Trucks | 412 558 | 42 902 | 362 492 |
| Medium Duty Trucks | 74 103 | 73 946 | 68 969 |
| **Brazil** | | | |
| Heavy Duty Trucks, pcs | 63 572 | 77 841 | 85 198 |
| Medium Duty Trucks, pcs | 25 888 | 26 309 | 22 589 |
| **China** | | | |
| Heavy Duty Trucks, pcs | 1 178 002 | 1 119 112 | 1 114 303 |
| Medium Duty Trucks, pcs | 235 708 | 161 468 | 133 927 |
| **Grand Total:** | **12 860 425** | **12 813 738** | **12 960 126** |

The below Table 3.2 shows the main financial figures of the company during last three fiscal years.

Table 3.2 PKC GROUP financial performance [7]

| **PKC Group Results (Euros, In Million)** | **FY 2018** | **FY 2019** | **FY 2020** |
|---|---|---|---|
| Sales | 1,043 | 1,176 | 1,177 |
| EBITDA | 72 | 105 | 120 |
| Finance Costs | 7 | 6 | 8 |
| Depreciation and amortization | 31 | 30 | 41 |
| Profit before tax | 36 | 72 | 73 |
| Taxes | 2 | 16 | 17 |
| Profit after tax | 33 | 55 | 56 |
| Minority Interests | 5 | 3 | 2 |
| PAT (concern share) | 28 | 52 | 54 |

## 3.4 Manufacturing processes

EDS manufacturing is considered as labour-heavy and mostly manual process; however, parts of the processes can be done by using automatization and machinery with several flexibility requirements. Below is described the main production steps of typical customer specific wiring harness production:

1. Automated cutting and crimping of wires. Flexible manufacturing system. Results are different semi-products. High-mix batch production;
2. Semi-automated processing of cut wires. Stand-alone machinery and workstations. Results are different semi-products. High-mix batch production with following operations:
   2.1. Removing insulation from wire ends for multicore cables;
   2.2. Retro crimping of terminals to wires;
   2.3. Ultrasonic welding for battery cables;

3. Marking of connectors with inkjet printers. Stand-alone machinery and workstations. Results are semi-products. High-mix batch production;
4. Automated cutting of insulation materials (protection tubes). Stand-alone machinery and workstations. Results are semi-products. High-mix batch production;
5. Manufacturing of pre-assemblies (filling connector housings partially with crimped wires). Manual assembly workstations. Results are semi-assembled products. High-mix batch production;
6. Collecting pre-assemblies for one final product order;

7. Assembly of bundling several pre-assemblies together as sub-assembly and adding components. Manual workstations. Results are semi-assembled final goods. Sequence production;
8. Final assembly – joining sub-assemblies together with straps and ties, connecting free end wires to connector cavities, ultrasonic welding of splice nodes and adding additional components to finalize product. Manual workstations with position control and operator guidance systems. Results are semi-assembled final goods. Sequence production;
9. Partial retro crimping terminals to final product. In case terminals do not fit through insulation tubes or wire lengths needs to be adjusted on final assembly board, crimping is done after assembly of the wiring harness. Stand-alone machinery and workstations working as a production line in one piece flow.
9. 100% connectivity and partial component presence check (tie clips, manifolds, spot tapes). Sequence production using with one-piece flow. Manual workstations with operator guidance systems;
10. Packing & Sequencing. Ready and checked products are packed to customized packing bags or boxes on manual workstations. Product labels are added to the package. Packed products are loaded into carrier racks according to consumption sequence at customer production site.

Figure 3.3 displays the manufacturing process flowchart of customer specific wiring harness together with decision making points for handling non-conformities during the manufacturing process. The process steps with light orange background represent the main manufacturing steps listed in section 3.4, process steps with blue background represent optional processes (not applicable for each product) and decision-making steps.

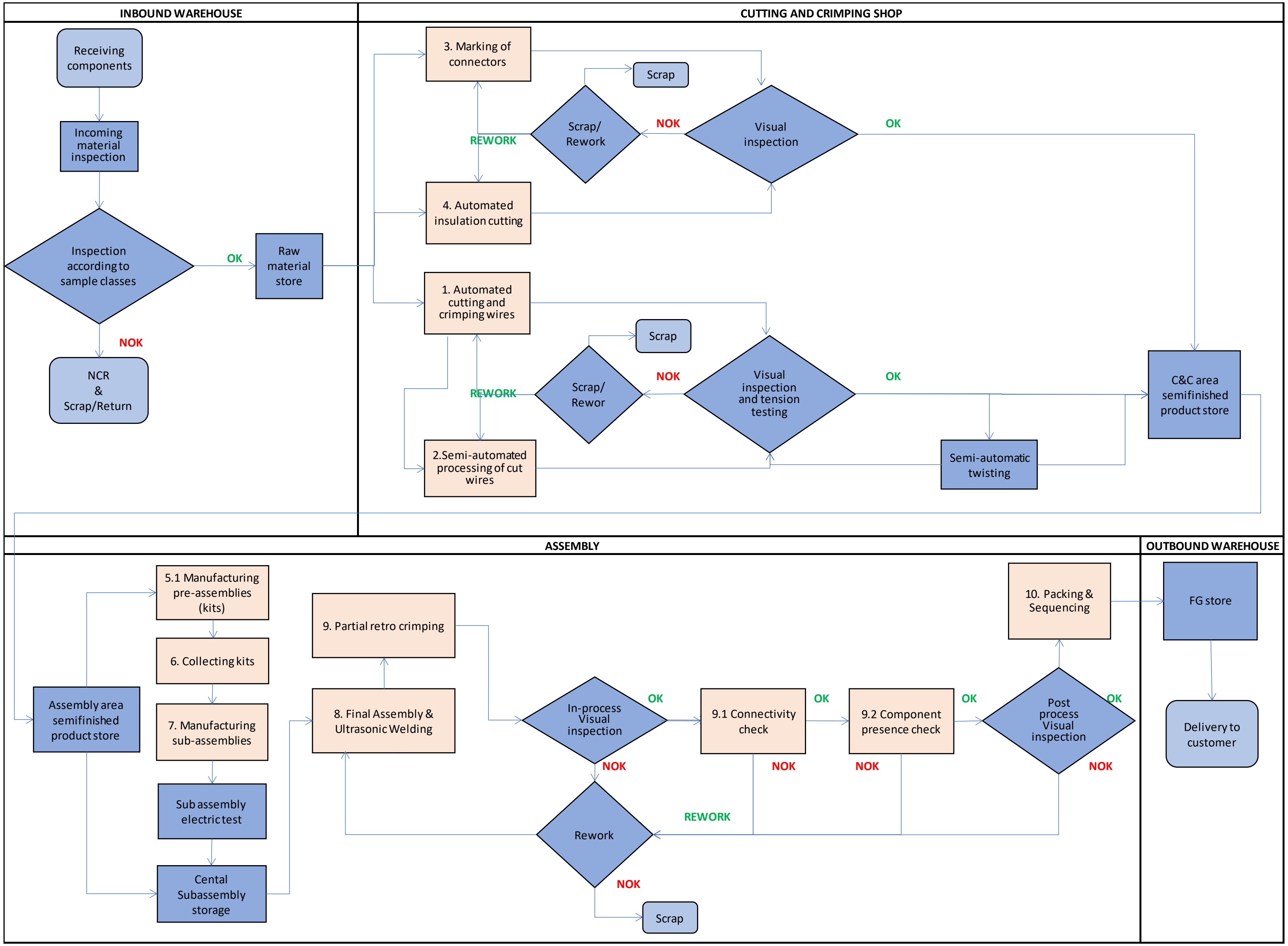


Figure 3.3 EDS manufacturing flowchart

## 3.5 Program management in PKC Group

PKC Group has diverse customer range and therefore handles simultaneously several new product launches. Most of the automotive customers require APQP or similar method for managing new launches. PKC Group has introduced Program Management and Launch Process (PLMP) which is used to define and monitor required activities from each department which is participating in the launch procedure. A program in PKC Group is and umbrella term which covers the complete lifecycle of a business award. Program management covers all functions participating in the program, New Product Introduction procedure in the other hand covers activities which are needed for industrialization of a newly awarded program. 5 main steps of a program are shown on Figure 3.4.

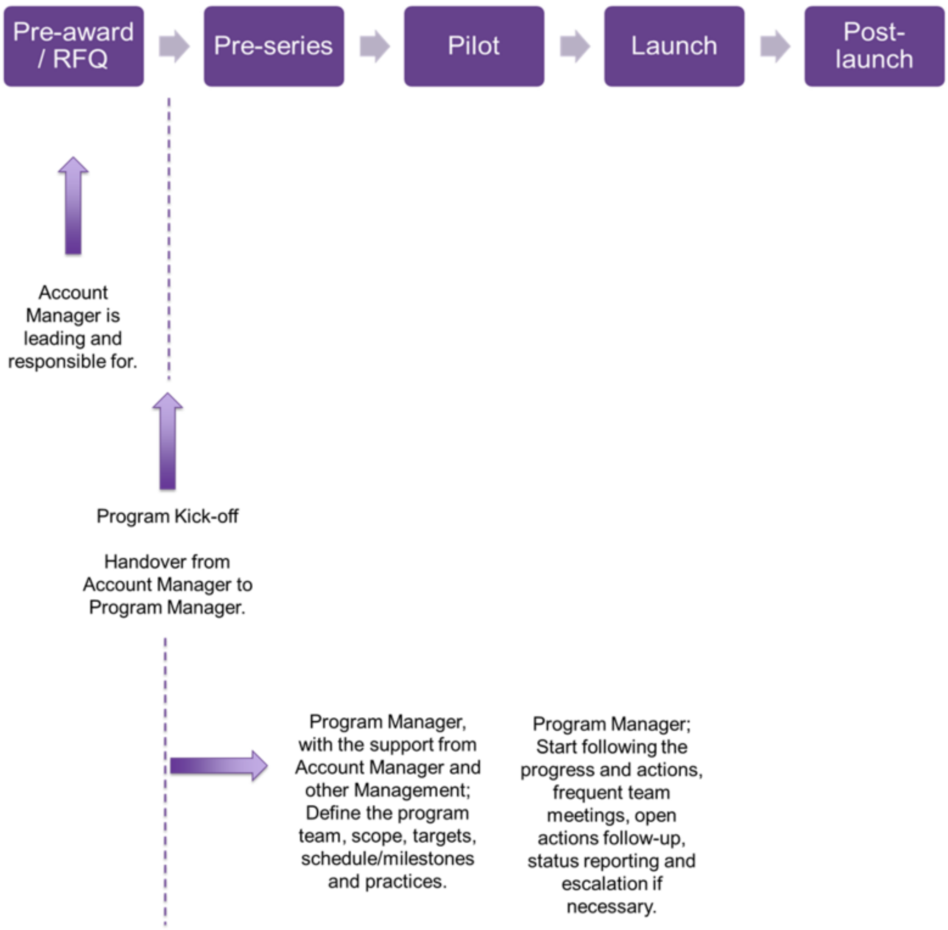


Figure 3.4 PKC Group program lifecycle diagram [14]

For each program is nominated program manager. In PKC Group EU&SA division are working 4 program managers who belong to Sales Engineering department. [15] Program Manager is leading a cross-functional team and is overseeing the program to ensure that the desired results are achieved with the most efficient resources. Main responsibilities of a program manager are as follows:

1. Define and setup a new program (basic information about the program);
2. Define a program team;
3. Define a program schedule and assign activities to appropriate persons;
4. According to agreed program practices, start managing, coordinating, and following program execution and progress. [14]

## 3.6 New Product Implementation process in PKC Group

In PKC GROUP a procedure is designed to ensure that there is a process for New Product Implementation and to facilitate a consistent approach when launching new products. NPI procedure sets out the process and tools to be used for industrialization of Electrical Distribution Systems production after the nomination of new business award. Significant new model year changes are also included to the scope.

Company's top management decides the manufacturing location where to implement that new product, usually this is determined during the request-of-quotation process, however a later change and decision can be possible in some cases. [16]

The NPI activities are executed through central NPI organization and local NPI project organization in the manufacturing locations. NPI is part of program management procedure with clear focus and responsibility of industrialization and related manufacturing engineering. A NPI project team is formed on project basis and consist of a Project Leader who belongs to NPI organization and a team of engineers and technicians who belongs to NPI organization and plant manufacturing engineering organization.[16] In PKC Group EU&SA division permanent NPI resources consists of 10 employees – NPI Manager, 2 Plant NPI Leaders, 5 project leaders and 2 regional process engineers. [15]

The below chart on Figure 3.5 sets out the typical product cycle through the different phases of the project from initial process design and prototyping right through to Serial Production and ramp up.  There is gradual hand-over process of manufacturing engineering tasks from NPI team to plant manufacturing engineering team during launch period.

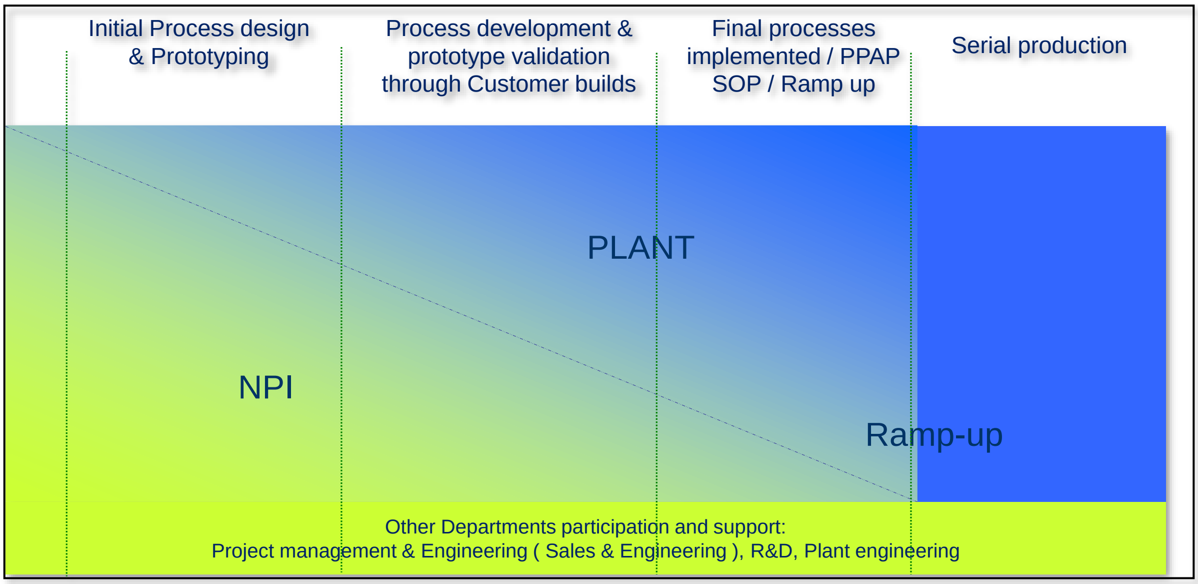


Figure 3.5 NPI methodology chart [16]

The Internal interfaces are regulated through the Procedure of Responsibility Matrix where it describes the roll (Responsible / Support) of each department during the project life. This is a key document which details all key tasks during a Product Launch and which department takes the lead on each activity and what are the key support Departments. Detailed responsibility Matrix is maintained by Program Management team and part of Program Management procedure. However, the responsibilities matrix has not been updated as long as from year 2015 and therefore is not adjusted with the organizational changes and expansion of the company. Below in Figure 3.6 is visualized the interconnection between key functions participating in new product launch.

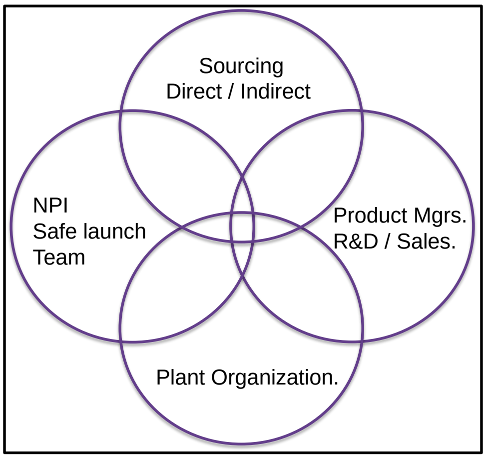


Figure 3.6 Cross-functional relations of NPI procedure [16]

NPI team is tracking all key activities using NPI Timing Plan template. Tracking files are available on shared location known for responsible Project or Program Manager. NPI team is following up all activities internally with the members from manufacturing location team. NPI project leader participates on regular project review meetings established by Project or Program Manager and presents status of activities. In case of deviating from initial timing, NPI project leader must provide recovery actions or escalate issue to Project or Program Manager in case there is no clear recovery action available. [16]

NPI Timing Plan is covering status of key actions. For the key tasks individual activity plans should be prepared using PKC action plan templates. Individual activity plans are needed for following and planning tasks such as assembly drawing and board preparation, manufacturing data preparation, workplace build and installation, test table build and installation, kit break and LAD instructions preparation, layout preparation, crimping tools ordering and preparation.

All active NPI projects are reported monthly and project status is presented by plant NPI Leader on monthly "New Production Implementation Review" call 3rd week of each month. This review meeting includes complete plant management. Plant NPI Leader and NPI Manager are also participating on monthly steering group meetings hosted by program management team and report NPI activities status upon request. [16] Table 3.3 gives an overview of NPI procedure in PKC Group prior the case study product launch.

Table 3.3 PKC GROUP New Product Implementation procedures [16]

| **Pre-Award / Request for Quotation Phase** |
| --- |
| • CAPEX information including but not limited tooling prices, qty, delivery and set-up times in weeks, usage% in the project, ownership by contract, capacity assumptions and projected delivery schedule;<br>• NPI team member evaluates product BOM, BOL, productivity assumptions, equipment availability in plant. Based on that list of needed tools and equipment are inserted to MRP system;<br>• NPI team is responsible to evaluate frontloading costs which are needed for starting the project. |
| **Project kick off Phase** |
| • Regional NPI department nominates responsible NPI project leader;<br>• NPI department receives key milestones from program manager:<br>o Customer documentation release dates;<br>o Standard BOM and BOL release dates;<br>o PPAP dates;<br>o Pre-build dates;<br>o SOP dates;<br>• NPI project leader creates NPI timing plan which includes all activities which are scope of NP procedure together with responsible persons, start and end dates. |

Table 3.3 Continued

| Planning and development phase |
| --- |
| • Develop main manufacturing process flows (Carrousel / Stationary boards / Test concept.);<br>• Review and update Initial Tooling & Equipment plan considering developed process flows and equipment availability in plant;<br>• Initial Technology review and sourcing & development of equipment and suppliers (if new processes are involved);<br>• Prepare the Capex request;<br>• Review Initial Labour estimations and floor space requirements. Present results with plant project team for approval;<br>• Develop detailed timing and activity plans for NPI tracking and update on a regular basis;<br>• Ensure that Material orders are added to the system for pre-build events and samples which are needed for specific tools ordering and/or validation;<br>• Participate with the Project Manager in preparing the overview summary for Management and target Plant organization;<br>• Lead development of the initial Master assembly boards for prototype and pre-build events with the cross-functional teams from the Launch Plant;<br>• Support the prototype builds with leading tooling, shop floor and manufacturing system preparation with the cross-functional teams from the Launch Plant. |
| **6.4 Industrialization phase** |
| • Firm up the Capacity calculations related to Directs employees, equipment, floor space, line capacity;<br>• Involve the target Plant/s in daily manufacturing engineering activities, track open issues;<br>• Final process development together with Plant Organization considering agreed shift patterns and Customer volumes;<br>• Lead development of the assembly board and test table designs for serial production using lessons learned from the prototype builds and experienced gained from past launches;<br>• Support the Manufacturing Engineering in the Launch locations related to layouts, line balancing and final process flow;<br>• Ensure tooling & Equipment is available in a timely manner by tracking the orders, delivery, and installation;<br>• Support the PPAP builds with leading tooling, shop floor and manufacturing system preparation with the cross-functional teams from the Launch Plant;<br>• Prepare Ramp up plans together with target Plant/s considering Customer inputs and using ramp-up criteria definition;<br>• Analyze the Customer forecasts to verify the capacity installed and to flag any unusual order patterns from the Customer, flag issues to the Project Manager and Account Manager;<br>• Coordinate the Capacity verifications and process validation with the Mfg. Plant through process validation builds. |

Table 3.3 Continued

| **6.5 Ramp-up + 90-day phase** |
| --- |
| • Track the planned Customer ramp up versus real orders;<br>• Track output from the Manufacturing Plant and ensure quantities are in line with Customer orders, address any process bottlenecks which are appearing and escalate to Management to ensure extra resources are defined to correct any negative outcomes related to the ramp up;<br>• Continue to track all open issues until closure;<br>• Support the Mfg. Plant to make process changes where needed to fulfil Customer demands;<br>• Phase out from the Project as agreed with Management, usually 90 days post full ramp up. |

# 4. STRATEGIC FURURE TRUCK PROGRAM OVERVIEW

## 4.1 Products overview

SFTP – Strategic Future Truck Project – is homogenised global truck platform by Daimler Trucks AG. Heavy duty product range is marketed under Daimler Actros and Daimler Arocs brand name (see Daimler Trucks Actros and Arocs under Graphics). [17]

SFTP wiring harnesses serve the power supply of electrical and electronic consumers as well as the transmission of signal and control currents. Electrical and electronic properties are taken from the respective wiring diagrams, system documents and the basic plans provided by the customer. Customer provides data in the form of netlists and wiring harness topology (basic plan). Beyond the electrical properties, the wiring harness design data contains elements for routing and fastening. The wiring harnesses are ordered as customer-specific variants with a low repetition rate. Annual volume forecasted by customer is 129 600 truck sets of wiring harnesses. [18]

Table 4.1 gives overview of nine products belonging to SFTP wiring harness programme. Designation shows area on the vehicle where the harness is installed, models define differences in the product which are related to different vehicle type, repetition rate shows how many identical product configurations are ordered per week, annual changes show how many times per year the product data is updated by the customer. [17]

Table 4.1 List of wiring harnesses belonging to SFTP program [17]

| **ID** | **Designation** | **Models** | **Repetition Rate (pcs. /1000)** | **Annual changes (pcs.)** | **Part nr. Count (pcs.)** |
|---|---|---|---|---|---|
| XVK81 | Chassis | LL, RL, LL GGVS, RL GGVS | 2,5 | 6 | 6480 |
| XVK82 | Front Bumper | - | 54 | 2 | 40 |
| XVK83 | Engine | MDEG LL, MDEG RL, HDEP LL, HDEP RL, OM460 LL, OM460 RL | 13,6 | 3 | 230 |
| XVK84 | Dashboard | LL, RL | 2,4 | 5 | 1227 |
| XVK85 | Front Wall | - | 14 | 2 | 39 |
| XVK86 | Roof | Standard-, Aero-, Hoch-/Giga-, Flach-, Abgesenktes-Dach | 6,1 | 5 | 595 |
| XVK87 | Left Door | - | 300 | 2 | 38 |
| XVK88 | Right Door | - | | | |
| XVK89 | Rear Wall | - | 9,3 | 2 | 63 |

The base plan (topology plan) defines the geometric structure of a wiring harness and the position of the electronic components in the vehicle. The wiring harness topology is a star-shaped network, which means there are no ring-shaped connections. The routing path of each line connection between two nodes (plugs, cable lugs, welding points etc.) is thus clearly defined. Base plan is created by customer using Capital Harness XC wiring design software and sent to the contractor as a complete data via web portal. With the Harness Package, no drawings of the basic plans are generally sent. If required, drawings can be generated using harness diagram data. [18]

Wiring harness geometries are assigned to line groups. The line groups are structured as A-object numbers and contain the lines that are to be installed in the wiring harness when ordering these A item numbers. For each vehicle order, the cable sets are created as customer-specific cable set variants (KSK). These so-called XVK sets contain the A-object numbers of all line groups required for a vehicle wiring harness and the number of the basic plan to which they are to be mapped. The resolution of a wiring harness variant from the 150% wiring harness documentation ("Harness Package") is carried out by the contractor. [18]

As shown on table 4, the program includes 9 end products which consists of a total of 8712 submodules (A item numbers). All item data need to be inserted to PKC Group ERP system databases – CWise application where is created bill of labour (BOL) and bill of material (BOL), COP application where is created cutting and crimping list of each product. After item data is created in PKC databases, it is possible to carry detail analyse for manufacturing concept definition, tooling, and capacity.

A selection of product images is shown under the graphics section.

## 4.2 Supply chain setup

Orders between customer, PKC Group and PKC Group's suppliers are handled using EDI method. EDI is a standardized method for transferring data between different computer systems or computer networks. It is commonly used for sending orders to warehouses, tracking shipments, and creating invoices. EDI is an easy way to transfer order information to the locations where the goods are stored. Some common EDI formats include X12 (United States), TRADACOMS (United Kingdom), and EDIFACT (International). [19] Table 4.2 provides overview of order data sent from Daimler AG to PKC using EDI interface.

Table 4.2 Delivery Release Order [20]

| **Delivery Release Order for A-Item Number** |
| --- |
| Preview over 12 months based on sales forecast.<br>Data for months 1-3 inclusive daily, remainder on a monthly basis.<br>Weekly supplement: Monday to Tuesday<br>Main batch at beginning of the month.<br>Daily transfer of all order and/or A-item number changes with the next delivery release order.<br>Forwarding of delivery release order takes place at approx. 3:30 am. |
| **Delivery Release Order for Variants (XVK sets)** |
| Daily generation.<br>Data up to 20th day before consumption inclusive daily.<br>All order and/or variant changes up to approx. 11:30 am are already transferred with the next delivery release order.<br>Forwarding of delivery release order takes place at approx. 3:30 am. |

Customer has two manufacturing locations to which PKC Group need deliver products – Wörth in Germany and Aksaray in Turkey. Depending on product, JIS or JIT deliveries are required. [20] A just-in-time system of manufacturing and delivery is based on preventing waste by producing only the amount of goods needed at a particular time, and not paying to produce and store more goods than are needed. [21] The JIS process is a further development of JIT delivery. With just-in-time method, the parts are delivered to the assembly line at the right time and in the right sequence and position. There, the final assembly of the components to the existing construction takes place immediately. [22] PKC Group management has decided to use production location in Smederevo, Serbia for manufacturing the goods.

Daimler Truck AG has defined types and models of special load containers and bags in logistics specification book. Responsibility of PKC Group is procurement of specified carriers following Daimler AG instructions and ensure availability all time. Separate packing instructions are provided for each product. Therefore, there is no need for developing packaging method by the supplier, only validate and train the personnel to follow the packing instructions.

Customer Daimler Truck AG has also defined delivery and data transfer timeline presented on Figure 4.1. Based on given timeline there are 3 days booked for transit and 3 days where the customer is not making changes to order content.  PKC Group received a task to prepare internal production and delivery timeline which will match customer requirement. The outcome is shown on Figure 4.2.

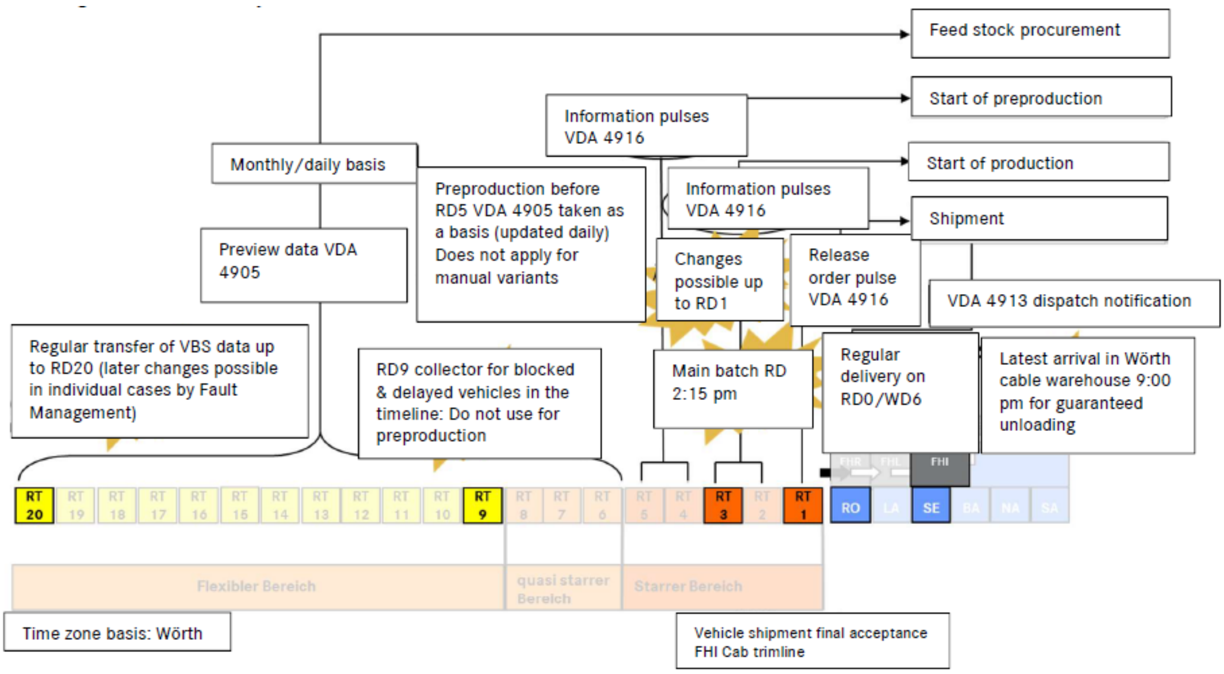


Figure 4.1 Wiring harness JIT/JIS system connection [20]

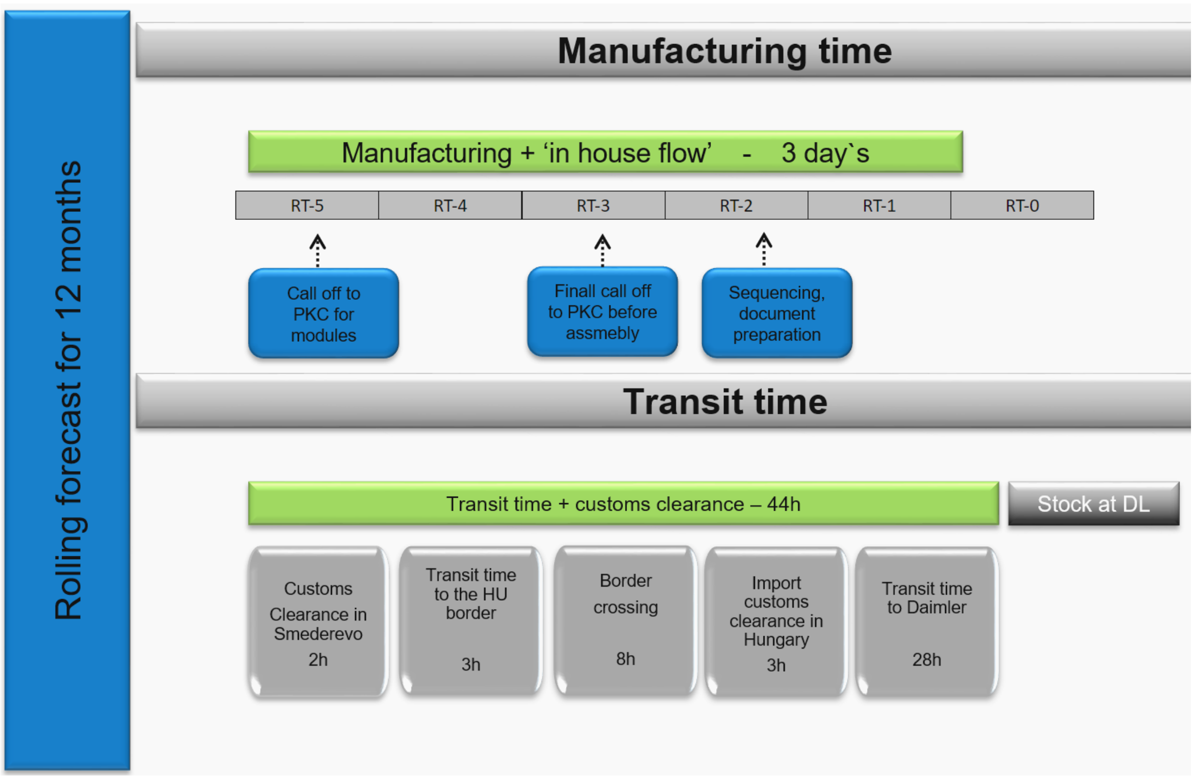


Figure 4.2 Production and delivery timeline [23]

## 4.3 Planned start of deliveries

Since wiring harness production is labour-intense high-mix and high-volume production, ramping up the production must be carried over extended timeline. Also, the JIS production concept does not allow the supplier to build any significant buffer stocks of any product. Therefore, PKC Group and Daimler AG have agreed that deliveries of SFTP wiring harnesses will be started in incremental schedule where the products are divided to 4 groups and start of deliveries are split between 3 product consumption destinations (manufacturing unit in Turkey, knock-down vehicle manufacturing unit in Germany and main manufacturing unit in Germany). Figure 4.3 presents the production start timing agreed by customer and supplier in December 2021.

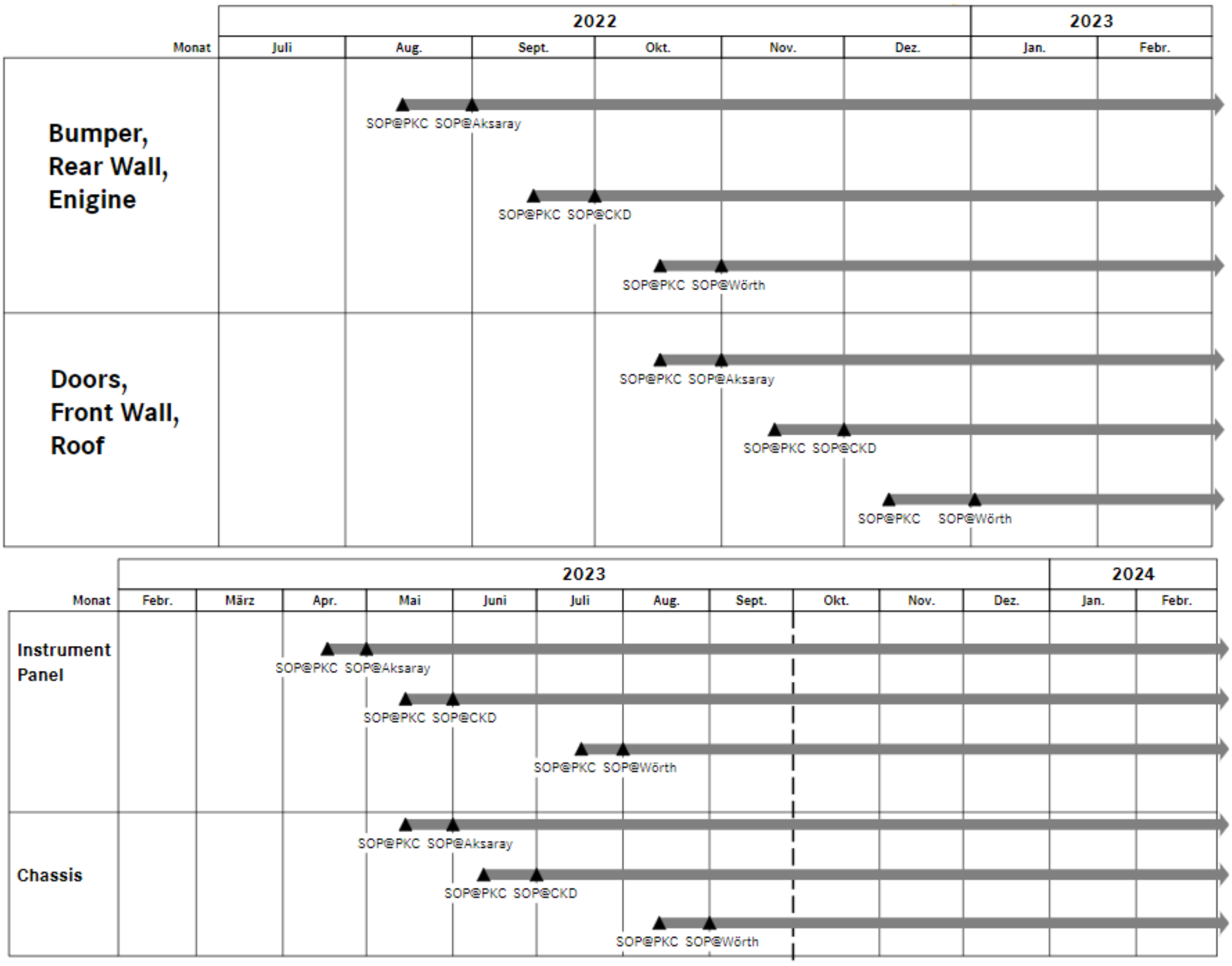


Figure 4.3 Start of deliveries by product and consumer [24]

## 4.4 Implementing lessons learned from previous launches

During year 2020 PKC Group has launched 2 significant size customer programs in target manufacturing unit (Smederevo plant in Serbia). Both product launches did not meet the targeted production output and caused extra costs to company mainly due extra freight cost and higher than planned worker headcount due to not enough training before ramp-up. Therefore, a lessons learned workshop was held in company where all the main problems of the previous launches were analysed by the project team and plant management. As an outcome, following strategic agreements were formulated to be considered when planning and executing SFTP launch:

- Ramp-up curves for complex products need to be prolonged compared to company's standard approach from previous launches which were between 4 to 8 weeks;
- First production year productivity targets need to be reduced from previous 60-85% of productivity to 50-85% of productivity;
- There should be minimum 3 trial builds for process validation before the launch. Trial builds shall not be skipped due to any organizational reasons;
- Evaluation of launch readiness and trial builds did not have agreed metrics. Traffic light system has been used which results are subjective and cause disagreement between project team members. To overcome this, each trial should be documented and rated using specific check sheet with 100 rating points;
- Traditional cutting method (cutting each position to exact length together with automatic crimping) is not working for Daimler production data due to thousands of different length variants. Mix of cut semi-products need to be reduced and automatic crimping must be replaced with semi-automatic processes;
- Each product groups need to have dedicated manufacturing engineering resources who are hired in advance of starting the project;
- Programs with significant scope need to have dedicated program and product managers and nominated representatives from support functions, critical support

functions (indirect purchasing, costing, production planning) should nominate dedicated persons working full-time with the new launch;

- Due to high amount of wrong wire pinning to cavities when starting to produce new harnesses, the test electric test tables output during ramp-up should be considered lower as normal standard time and the quantity of test resources shall be calculated accordingly;
- Due to high number of missing wires from pre-assembled kits, pre-assemblies of complex harnesses should have intermediate circuit presence check before reaching to final assembly station as adding the missing circuits to finished product requires rework which has duration equal to building a completely new harness;
- The rework ratio of produced harnesses during ramp-up should be evaluated and taking into consideration when planning the quantity of workstations dedicated for reworking faulty products;
- Reporting to top management need to be improved. Instead of 4 gate reviews after each project phase (planning, prototyping, pre-builds and ramp-up), management reviews need to be held minimum once per month.

## 4.5 Pre-build plan for process validation

As a major lesson from previous product launches, process validation methodology improvement has been requested for successful product launch of the SFTP program.

To validate processes, tools, capacity estimations and train operators, a series of pre-build events are scheduled as part of the launch plan. Based on the phase of the build, the focus of pre-builds shifts from initial assembly fixture and product data validation until complete process validation together with work time measurements. The products manufactured during such build events must be complete functional but are not intended to assembly to any vehicles (expect for fit checks). The build phases were evaluated and established for the SFTP launch as following:

- FOT (first of tool) build – producing 10 sets of wiring harnesses over week period using series intent workstations. Main goal of FOT build is to check and evaluate DFM (design for manufacturability), assembly board design and validate theoretical cutting lengths. Workstations are set up as stationary units where the complete final assembly is done (instead of standard conveyor line setup). During FOT build pre-assembly and post-assembly processes are not required to follow control plan and serial tooling;

- PV (process validation) build – producing 50 sets of wiring harnesses over week period using series level workstations and limited size conveyor line together with final connectivity test. The shop floor setup must cover all process steps and serial tooling as defined on the layout and control plan without the full series capacity requirement. Main goal of PV build is validating process, measure line balance, identify bottlenecks in process, verify that all findings from FOT builds are fixed;

- Interim PPAP build – producing 200 sets of wiring harnesses over week period using full size assembly conveyor and production team. Interim PPAP will be witnessed by customer project team who, in case of successful build result, give approval to start ramping up the production.

Each build will be scheduled with 2-6 weeks between each event to allow time to evaluate findings and corrective actions. In-between build phases, operators who are hired for these events are either sent to work in other departments or they continue their training by continuously dismantling and assembling the products. The build schedule also follows customer document change release schedule, so company's data preparation team needs to update product data between each build event. Based on production start milestones given by PKC customer on figure 9, a pre-build schedule is prepared as shown on Appendix 1.

## 4.6 Project organization and management

According to program management procedure described in chapter 3.5, a project organization was put together to carry the production launch activities. Considering scope and complexity of project, key positions must be dedicated only for SFTP program. PKC Group need to carry 20 new white-collar hires to fulfil the resources needed to launch the product. Figure 10 presents the organizational chart for the project team. The complete project team is coordinated by Program Manager. For manufacturing unit specific functions coordination, operations project leader role is established.

Although table 9 presents the project team, each function in plant organization had the task from plant general manager to evaluate resources need for implementing SFTP program and request new hires where needed. As an improvement compared to previous organizational chart, several key positions were hired. Increase of organizational chart are surrounded by a red box on Figure 4.4.

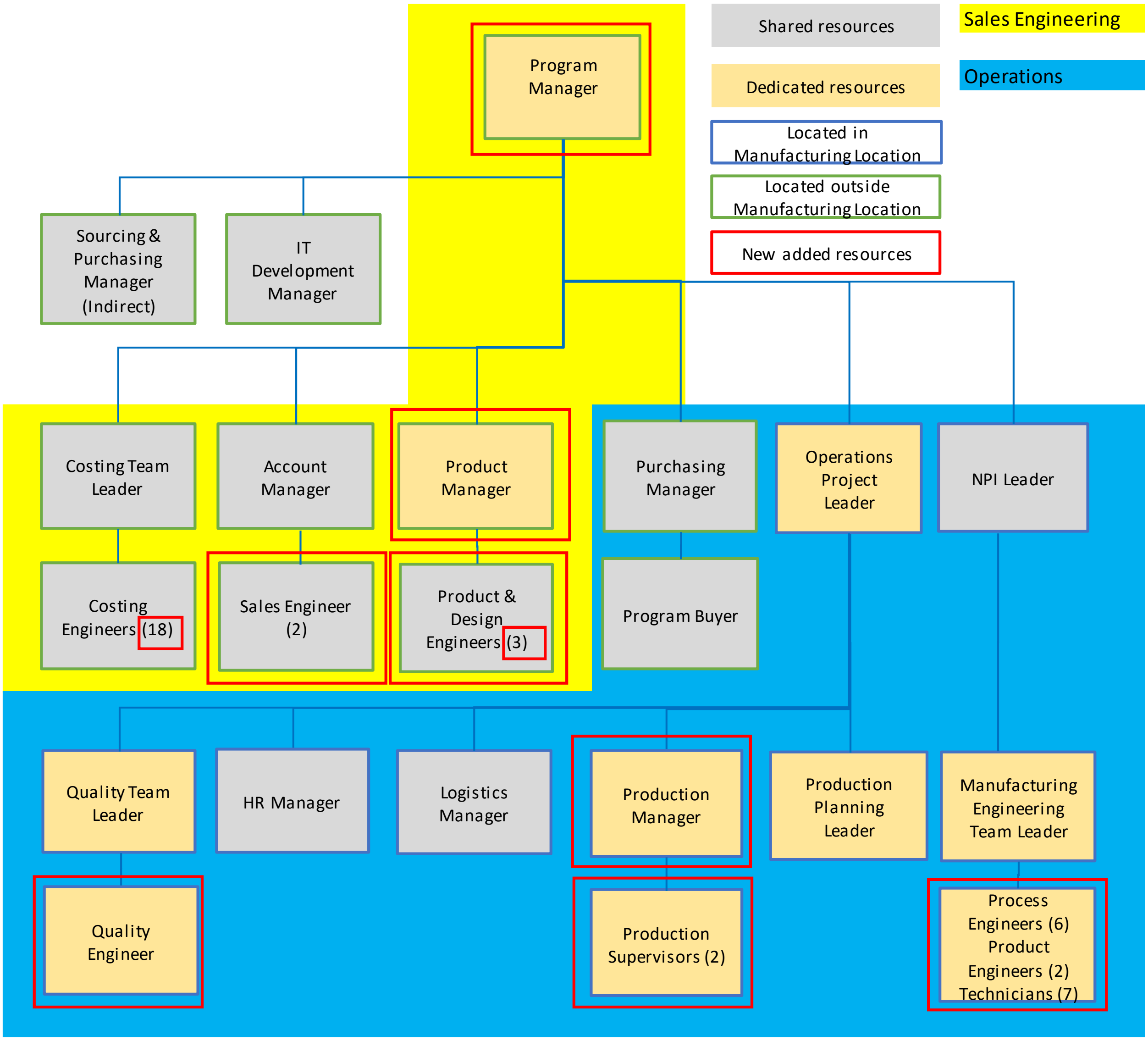


Figure 4.4 SFTP Program organizational chart

# 5. PRODUCT DATA ANALYZE AND CONCEPT DEFINITION

## 5.1 Direct labour analysis

As first order, direct labour quantity should be calculated. Direct labour definition is coming from value added works which are billed to customer and therefore described in bill of labour for each product. In PKC Group bill of labour is part of the product item data, which is created by costing engineers. PKC Group has implemented standard time system which uses component-based data to calculate and summarize needed operation times for products.

PKC Engineering team has identified all work phases which are related to components, made measurements, and built a standard time library based on the investigation. The work phases are divided to main and sub phases. The results are formulas which take into consideration component quantities, lot sizes and quality checks. As a result, when new item data is inserted to PKC database, work times are applied automatically by the ERP software based on component and lot size information. PKC Group standard time library includes 66 active main work phases and 991 active sub work phases. [25]

As described in chapter 4.1, PKC Group received from customer list of products which consists of 8712 different part numbers from which is composed 9 end products per vehicle. As the end products are highly customized and the customer did not provide annual volume information for each different part number, there is need for a reference product specification, which can be used both for price calculation and for resource need calculations. For that purpose, Daimler Truck AG has provided two reference specifications based on historical order data – one for low specification vehicle wiring harness set and one for high specification vehicle wiring harness set. High specification vehicles represent 70% of order volume and low specification represents the remining 30%. Based on given input, the average truck wiring harness set times were calculated. Table 5.1 represents main work phases per product. Appendix 2 displays sub work phases per product.

Table 5.1 Standard work minutes by main work phase for average truck set [26]

| Description | XVK81 Chassis (min.) | XVK82 Engine (min.) | XVK83 Bumper (min.) | XVK84 Dashboard (min.) |
|---|---|---|---|---|
| Assembling | 194,18 | 20,30 | 40,07 | 169,96 |
| Crimping | 11,34 | 0,15 | 7,31 | 35,75 |
| Electrical Testing | 11,37 | 1,64 | 2,41 | 15,08 |
| Final Assembling | 4,05 | 0,39 | 0,61 | 6,16 |
| Final Checking | 9,75 | 1,32 | 2,04 | 21,56 |
| Final Packing | 1,17 | 0,42 | 0,50 | 1,50 |
| Handling | 37,09 | 0,85 | 9,30 | 43,55 |
| Multicores cutting | 3,84 | | 1,48 | 6,34 |
| Sealed wires cutting | 7,38 | 1,01 | 1,33 | 0,28 |
| Wires cutting | | | 1,71 | 12,47 |
| Packing | 5,46 | 0,42 | 0,50 | 1,50 |
| **Total Worktime** | **285,63** | **26,48** | **67,24** | **314,15** |

Table 5.1 Continued

| Description | XVK85 Front Wall (min.) | XVK86 Roof (min.) | XVK87 Door L (min.) | XVK88 Door R (min.) | XVK89 Rear Wall (min.) |
|---|---|---|---|---|---|
| Assembling | 46,54 | 70,83 | 19,58 | 20,01 | 25,17 |
| Crimping | 0,92 | 2,29 | 0,48 | | 2,26 |
| Electrical Testing | 2,27 | 3,55 | 1,50 | 1,42 | 1,83 |
| Final Assembling | 0,77 | 0,99 | 0,55 | 0,50 | 0,72 |
| Final Checking | 3,22 | 4,47 | 2,07 | 1,84 | 1,68 |
| Final Packing | 0,42 | 0,54 | 0,22 | 0,23 | 0,25 |
| Handling | 18,99 | 5,13 | 1,78 | 1,53 | 2,40 |
| Multicores cutting | 0,38 | 0,46 | 0,18 | | 0,38 |
| Sealed wires cutting | 1,24 | | 0,62 | 0,61 | |
| Wires cutting | 0,72 | 2,71 | 0,80 | 1,03 | 0,78 |
| Packing | 0,42 | 0,54 | 0,22 | 0,23 | 0,25 |
| **Total Worktime** | **75,88** | **91,50** | **27,99** | **27,39** | **35,72** |

After alignment with the project team, it is agreed that absenteeism rate is 10% and rate of support blue collar workers (material handlers and quality inspection operators) is calculated by 20% of standard hours. As a lesson learned from same customer but different product program launches from year 2020, productivity targets for the post ramp-up phase are set on a very conservative basis and differ for product based on the complexity of the wiring harness. Using these factors, the needed headcount after ramping up the production is 2 895 operators. Split per product group is shown on Table 5.2. The operators responsible for wires and cables processing are shown on a separate category as cutting and crimping area is common production area serving all product lines. Also, material handlers are shown as common group as on the first phase of project is not defined exact split of these operators between each production area. The headcount for each product in table 5.2 is calculated by formula:

$$HC = \frac{T_{std} \times AV \times Pr}{t_{avy}} \quad (5.1)$$

Where:

HC is the required headcount of direct operators

$T_{std}$ is the total work time for one wiring harness in minutes

AV is the annual volume of the product

Pr is the targeted productivity compared to $T_{std}$ immediately after ramp-up

$t_{av}$ is the available working time in minutes in a year. 48 work weeks x 5 workdays x 3 work shifts x 440 minutes per shift.

Table 5.2 Direct labour calculation

| ID | Designation | Target productivity | Direct operators |
|---|---|---|---|
| XVK81 | Chassis | 35% | 1000 |
| XVK82 | Front Bumper | 90% | 59 |
| XVK83 | Engine | 35% | 88 |
| XVK84 | Dashboard | 70% | 512 |
| XVK85 | Front Wall | 90% | 101 |
| XVK86 | Roof | 70% | 160 |
| XVK87 | Left Door | 80% | 40 |
| XVK88 | Right Door | 80% | 40 |
| XVK89 | Rear Wall | 90% | 47 |
| Common | C&C / process | 80% | 180 |
| Common | Absenteeism 10% | N/A | 223 |
| Common | Material handler and Q-inspection 20% | N/A | 445 |
| | | **Total Direct headcount:** | **2895** |

## 5.2 Final assembly equipment analysis

General wiring harnesses manufacturing process carries standard steps as shown in figure 4. Production concept definition means therefore following decision making points which are driven from evaluating the duration of individual work phases and order volumes

- Evaluating whether harnesses final assembly is done on stationary workstations or in a conveyor line. A conveyor line is used when there is required minimum 6 operators per work shift to make the task;

- Evaluating whether harness assembly is needed to split to steps (final assembly and pre-assembly). In case there is needed conveyor line with more than 6 workstations, the rule of thumb is to keep 60% of work content on pre-assembly workstations and 40% on final assembly workstations;

- Evaluating size and quantity of conveyor line. Conveyor lines have paired number of workstations. First 50% of workstations are used for laying the wires and pinning. As these work steps are considered as most complex, one operator per workstation is used. Second 50% of workstations are used for closing the harness -adding ties, taping, adding branch insulation. In this area more operators can be used per workstations, leaving 2,5 meters working space for each worker;

- Maximum manageable conveyor is 24 workstations and minimum manageable takt time is 1,5 minutes;

- evaluating need for specific tasks during assembly which either can be done on the conveyor line or offline depending on share of work time compared to complete work time. Such work phases are ultrasonic welding, continuous taping, clip, and brackets assembly;

In case of SFTP wiring harnesses, each harness sample was requested from customer who ordered the samples from the predecessor supplier, also each harness technical drawing and standard BOL was evaluated, based on that following decision specific for SFTP product range were made:

For rear wall and front wall harness branch taping and clip assembly should be separated as the harnesses have full branch taping and long (more than 30 cm) branches. This design allows to use automatic taping machines which are offline tools. In this case harness is mounted in conveyor line without taping, taping is done after taking the harnesses from conveyor and clips and other extra components can be added on dedicated workstations after the taping.

As Door driver and Door passenger harnesses share mirrored geometry and identical component list, these products production can be combined to one manufacturing area and to the same final assembly conveyors.

Besides previous mentioned criteria, target efficiency and shift pattern are necessary to be defined for calculating the needed number of workstations, final assembly conveyors. Target productivity has been shown on table 7. Shift pattern guided by company management is 3 shifts during 5 workdays. 440 minutes are considered as clean working time in each shift. Summary of workstation calculation is presented on table 8.

Shift pattern and amount on conveyor lines are used to calculate amount of assembly teams. One assembly team is group of people who work on a given line together with support workstations (preassembly stations, test tables, packing and other post-process stations). Each crew will have target production output which will be basis for ramp-up plan definition. As an example – dashboard harness will be produced in two 24-station conveyor lines in 3 shifts, which means two crews working per shift and total six crews working on dashboard harness production area. Considering daily volume of 540 harnesses, each crew need to produce 90 harnesses during their workday. Table 5.3 shows summary of workstations which is calculated by following formula:

$$Sc = \frac{DV \times AT_{std \times} Pr}{t_{avd}} \tag{5.2}$$

Where:

Sc is quantity of calculated value of workstations

DV is the daily volume of the product

$AT_{std}$ is the assembly work time for one wiring harness in minutes

Pr is the targeted productivity compared to $AT_{std}$ immediately after ramp-up

$t_{avd}$ is the available working time in minutes in a workday. 3 work shifts x 440 minutes per shift.

Table 5.3 Production setup and workstation calculation

| ID | Description | Stage | Daily Volume (pcs.) | Assembly time/product (min.) | Target Efficiency | Stations calculated (pcs.) | Stations actual (pcs.) | Workplace setup |
|---|---|---|---|---|---|---|---|---|
| XVK84 | Dashboard Low LHD | Final | 146 | 77,2 | 50% | 11,37 | 72 | Conveyor 24 station x 2, 1,5 operators per workstation |
| XVK84 | Dashboard High LHD | Final | 340 | 85,6 | 50% | 29,42 | | |
| XVK84 | Dashboard Low RHD | Final | 16 | 77,2 | 50% | 1,26 | | |
| XVK84 | Dashboard High RHD | Final | 38 | 85,6 | 50% | 3,27 | | |
| XVK84 | Dashboard Low LHD | Pre | 146 | 79,8 | 50% | 17,63 | 73 | Stationary workstations |
| XVK84 | Dashboard High LHD | Pre | 340 | 92,4 | 50% | 47,63 | | |
| XVK84 | Dashboard Low RHD | Pre | 16 | 79,8 | 50% | 1,96 | | |
| XVK84 | Dashboard High RHD | Pre | 38 | 92,4 | 50% | 5,29 | | |
| XVK81 | Chassis Low | Final | 162 | 75,0 | 45% | 4,09 | 20 | Conveyor 4 stations x 4. Stationary workstations x4 |
| XVK81 | Chassis High | Final | 378 | 75,0 | 45% | 9,55 | | |
| XVK81 | Chassis Low | Pre | 162 | 45,0 | 45% | 3,07 | 24 | Conveyor 12 stations. Stationary workstations x8 |
| XVK81 | Chassis High | Pre | 378 | 45,0 | 45% | 7,16 | | |
| XVK81 | Chassis Low | Pre | 162 | 90,0 | 45% | 24,55 | 70 | Stationary workstations |
| XVK81 | Chassis High | Pre | 378 | 90,0 | 45% | 57,27 | | |
| XVK82 | Bumper High | Final | 378 | 20,0 | 70% | 8,18 | 16 | 2x Conveyor 8-station |
| XVK82 | Bumper Low | Final | 162 | 13,2 | 70% | 2,31 | | |
| XVK82 | Bumper High | Pre | 378 | 12,6 | 70% | 5,17 | 8 | Stationary workstations |
| XVK82 | Bumper Low | Pre | 162 | 8,1 | 70% | 1,42 | | |

Table 5.3 Continued

| ID | Description | Stage | Daily Volume (pcs.) | Assembly time/product (min.) | Target Efficiency | Stations calculated (pcs.) | Stations actual (pcs.) | Workplace setup |
|---|---|---|---|---|---|---|---|---|
| XVK83 | Engine High | Final | 378 | 24,0 | 70% | 9,84 | 24 | 2x Conveyor 12-station |
| XVK83 | Engine Low | Final | 162 | 22,2 | 70% | 3,89 | | |
| XVK83 | Engine High | Pre | 378 | 16,0 | 70% | 6,56 | 8 | Stationary workstations |
| XVK83 | Engine Low | Pre | 162 | 14,8 | 70% | 2,59 | | |
| XVK85 | Front wall High | Final | 378 | 18,5 | 75% | 7,05 | 12 | Conveyor 12-station |
| XVK85 | Front wall Low | Final | 162 | 17,1 | 75% | 2,80 | | |
| XVK85 | Front wall High | Pre | 378 | 18,6 | 75% | 7,12 | 10 | Stationary workstations |
| XVK85 | Front wall Low | Pre | 162 | 17,8 | 75% | 2,91 | | |
| XVK85 | Front wall High | Clip | 364 | 18,6 | 75% | 6,85 | 10 | Stationary workstations |
| XVK85 | Front wall Low | Clip | 156 | 17,8 | 75% | 2,80 | | |
| XVK85 | Front wall High | Taping | 364 | 2,5 | 75% | 0,92 | 2 | Stationary workstations |
| XVK85 | Front wall Low | Taping | 156 | 2,5 | 75% | 0,39 | | |
| XVK86 | Roof High | Final | 378 | 42,5 | 70% | 17,39 | 54 | 2x Conveyor 18-station |
| XVK86 | Roof Low | Final | 162 | 31,1 | 70% | 5,45 | | |
| XVK86 | Roof High | Pre | 378 | 28,3 | 70% | 11,59 | 16 | Stationary workstations |
| XVK86 | Roof Low | Pre | 162 | 20,7 | 70% | 3,63 | | |
| XVK87 | Driver Door High | Final | 378 | 11,8 | 75% | 4,49 | 24 | 1x Conveyor 12-station |
| XVK87 | Driver Door Low | Final | 162 | 10,7 | 75% | 1,76 | | |

Table 5.3 Continued

| ID | Description | Stage | Daily Volume (pcs.) | Assembly time/product (min.) | Target Efficiency | Stations calculated (pcs.) | Stations actual (pcs.) | Workplace setup |
|---|---|---|---|---|---|---|---|---|
| XVK88 | Passenger Door High | Pre | 378 | 8,0 | 75% | 3,07 | 10 | 1x Conveyor 12-station |
| XVK88 | Passenger Door Low | Pre | 162 | 7,6 | 75% | 1,24 | | |
| XVK89 | Rear wall High | Final | 378 | 10,1 | 75% | 3,86 | 6 | Conveyor 6-station |
| XVK89 | Rear wall Low | Final | 162 | 1,8 | 75% | 0,29 | | |
| XVK89 | Rear wall High | Pre | 378 | 10,1 | 75% | 3,85 | 7 | Stationary workstations |
| XVK89 | Rear wall Low | Pre | 162 | 4,2 | 75% | 0,69 | | |
| XVK89 | Rear wall High | Taping | 364 | 2,5 | 75% | 0,92 | 2 | Stationary workstations |
| XVK89 | Rear wall Low | Taping | 156 | 2,0 | 75% | 0,32 | | |
| XVK89 | Rear wall High | Clip | 364 | 10,1 | 75% | 3,71 | 7 | Stationary workstations |
| XVK89 | Rear wall Low | Clip | 156 | 4,2 | 75% | 0,66 | | |

Besides conveyor lines and workstations, the setup of final assembly area requires investment of shop floor furniture and equipment for work instructions (computer sets), For each workstation on conveyor line is added computer set with barcode reader and label printer for identifying the semi-assembled kits. Produced kits are stored on storage racks with a 3:1 ratio compared to amount of pre-assembly workstations. List of auxiliary tools with quantities are displayed on Table 5.4

Table 5.4 Auxiliary equipment for assembly stations

| Auxiliary equipment name | Quantity (pcs.) |
|---|---|
| Computer set with monitor | 475 |
| Wired barcode scanner | 475 |
| Monitor holder | 475 |
| Pre-assembled kit storage rack | 75 |

Wiring harnesses for cabin interior (front and rear wall, doors, and roof) have all harness branches covered with continuous taping, therefore automatic taping machines are considered instead of manual taping. Main benefit of taping machine is controlled consumption of tape and as secondary benefit is the increased efficiency approximately 300% compared to manual taping. Table 5.5 presents calculation logic for taping machines using standard times from BOL for manual taping as reference and using 3 shifts with 440 minutes per shift for available time.

Table 5.5 Machine taping workstation calculation

| ID | Description | Daily Volume (pcs.) | Manual taping (min.) | Machine taping (min.) | Stations calculated (pcs.) | Stations actual (pcs.) |
|---|---|---|---|---|---|---|
| XVK85 | Front Wall | 540 | 26,3 | 7,9 | 3,2 | 4 |
| XVK86 | Roof | 540 | 39,5 | 11,9 | 4,9 | 5 |
| XVK87 | Left Door | 540 | 7,5 | 2,3 | 0,9 | 1 |
| XVK88 | Right Door | 540 | 7,8 | 2,3 | 1,0 | 1 |
| XVK89 | Rear Wall | 540 | 8,6 | 2,6 | 1,1 | 2 |

Significant amount of floor space is needed to store cut and processed wires before assembly area. Wires availability is the driver for seamless manufacturing process and the maximum uptime of automatic cutting machines is a key metric for a wiring harness manufacturing company. For minimizing the changeovers, orders with similar parameters of wires are terminals are collected over a period which allows cut bigger batches. As the period is longer than the immediate consumption, the cut wires need to have enough intermediate storage. Cut and crimped wires are stored in bundles on customized storage racks. Each rack has rods which can fit up to 500 pieces of cut wires. On the other each rod is usable for only one type of semi-product for avoiding mixing the wires during collecting process. This means if a semi-product has demand lower than 500 pieces, it will occupy a storage rod with maximum capacity of 500 pieces. Table 5.6 presents study for wire storage racks for SFTP project.

Table 5.6 Cut wire storage calculation

| ID | Designation | Daily Volume (pcs.) | Total positions/ harness (pcs.) | Average cuts/ harness (pcs.) | Cuts/week (pcs.) with 25% buffer | Storage rods (pcs.) | Storage racks (pcs.) |
|---|---|---|---|---|---|---|---|
| XVK81 | Chassis | 540 | 3000 | 185 | 124875 | 3000 | 75 |
| XVK82 | Bumper | 540 | 498 | 31 | 20925 | 498 | 13 |
| XVK83 | Engine | 540 | 2173 | 36 | 24300 | 2173 | 55 |
| XVK84 | Dashboard | 540 | 4473 | 461 | 311175 | 4473 | 112 |
| XVK85 | Front Wall | 540 | 268 | 37 | 24975 | 268 | 7 |
| XVK86 | Roof | 540 | 1221 | 91 | 61425 | 1221 | 31 |
| XVK87 | Left Door | 540 | 117 | 24 | 16200 | 117 | 3 |
| XVK88 | Right Door | 540 | 103 | 29 | 19575 | 103 | 3 |
| XVK89 | Rear Wall | 540 | 210 | 33 | 22275 | 210 | 6 |
| | | | | **Total** | **625725** | **12063** | **305** |

## 5.3 Ramp-up plan definition

A ramp-up is a significant increase in the level of output of a company's products or services. A ramp-up typically occurs in anticipation of an imminent increase in demand. While it is generally a feature of smaller companies at an early stage of development, a ramp-up can also be undertaken by large companies that are rolling out new products or expanding in new geographies. [27]

Ramping up wiring harness production is time consuming, main factors are labour intensity and high mix of products. Ramping up a wiring harness production line can take between 15 working days up to 110 working days. For each product in the SFTP program scope, individual ramp-up time duration and output curve need to be defined as first step. For that purpose, based on experience of previous program launches, PKC Group has established decision matrix will be used as a base for ramp-up planning. Appendix 3 shows the decision-making criteria and matrix. Initial proposal was made to plant management based on company criteria matrix, however the consensus on management review was to increase the ramp-up curves for each product and define different ramp-up curve duration on the same product line – longer for first crews and shorter for the later added crews. Table 5.7 presents result per product croup according to theoretical evaluation and outcome after management review. Appendix 4 presents calculated ramp-up plans for each product group taking into consideration time plan in Figure 11.

Table 5.7 Ramp-up duration per product group

| **ID** | **Designation** | **Circuit Count (pcs.)** | **Rating** | **Diversity/ Complexity** | **Cycle time (min.)** | **Theoretical Ramp-up (days)** | **Agreed Ramp-up (days)** |
|---|---|---|---|---|---|---|---|
| XVK81 | Chassis | 160 | Medium high | High | 9,8 | 55 | 70 - 110 |
| XVK82 | Front Bumper | 30 | Medium Low | High | 2,4 | 35 | 45 - 55 |
| XVK83 | Engine | 49 | Medium Low | High | 4,9 | 45 | 45 - 70 |
| XVK84 | Dashboard | 478 | High | Medium | 2,4 | 55 | 55 |
| XVK85 | Front Wall | 36 | Medium Low | Medium | 2,4 | 30 | 35 - 45 |
| XVK86 | Roof | 70 | Medium Low | High | 4,9 | 45 | 30 - 55 |
| XVK87 | Left Door | 30 | Medium Low | Low | 2,4 | 25 | 30 - 55 |
| XVK88 | Right Door | 30 | Medium Low | Low | 2,4 | 25 | 30 - 55 |
| XVK89 | Rear Wall | 19 | Low | Medium | 2,4 | 25 | 35 - 45 |

Based on defined ramp-up durations on table 5.7, customer timing plan shown on figure 4.3 and production concept defined on chapter 5.2, next task is to prepare ramp-up plan for each product group and individual crew who takes part of the ramp-up. The parameters what need to be considered are following:

- first line and crew have the longest duration ramp-up period since they face the most technical and organizational issues when starting production;
- when possible, avoid starting multiple crews for one week. The less crews starting simultaneously, the less problems can occur with training the operators and putting supervisors and trainers focus on single destination;
- PKC can sell wiring harnesses which are produced not more than then 10 working days before delivery due to customer specific content. Therefore, the start of

different crews must be aligned in a way that in one hand the customer milestones and delivery targets are met, but on the other hand production of excess products has brought to minimum.

The outcome of this exercise is shown on appendix 3.

## 5.4 Direct labour analyses

Direct labour plan is a document which defines direct labour headcount on a weekly basis for SFTP wiring harness program. Staffing plan has two vectors:

- Time schedule – how headcount is changing on a weekly level taking into consideration pre-build schedule (appendix 1) and ramp-up plan (appendix 1). The headcount requirement for each product group remains same between the pre-build phases to avoid loss of skills and extra costs and motivational problems which can occur when operators are sent to leave or work in other production areas;

- Headcount of production crews – following production setup calculation on Table 5.3, operators for each product group are divided to groups (crews) for which is added 10% absenteeism factor.

Monthly direct labour plan is presented on Table 5.8 and weekly labour plan is shown on appendix 5. Based on that plan the plant management develops a staffing plan. Staffing plan is a mix of planned new hires and transferring experienced work operators from other production lines, 4-6 weeks introduction and initial training need to be factored in when creating such plan. Finalized staffing plan is a basis for budgeting the plants labour for upcoming budget period.

Table 5.8 Direct labour monthly staffing plan

| **Year 2022 - direct labour/ month** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ID** | **Designation** | **January** | **Feb.** | **Mar.** | **Apr.** | **May.** | **Jun.** | **Jul.** | **Aug.** | **Sep.** | **Oct.** | **Nov.** | **Dec.** |
| XVK83 | Engine | 24 | 24 | 24 | 24 | 48 | 77 | 132 | 144 | 144 | 138 | 120 | 96 |
| XVK82 | Bumper | 9 | 18 | 25 | 44 | 62 | 71 | 80 | 106 | 106 | 106 | 102 | 88 |
| XVK89 | Rear Wall | 6 | 12 | 17 | 24 | 36 | 43 | 58 | 72 | 72 | 72 | 69 | 60 |
| XVK87&8 | Doors | 0 | 0 | 24 | 24 | 48 | 48 | 48 | 77 | 96 | 144 | 144 | 144 |
| XVK85 | Roof | 0 | 0 | 9 | 15 | 30 | 33 | 48 | 65 | 111 | 170 | 178 | 178 |
| XVK86 | Front Wall | 0 | 0 | 21 | 26 | 41 | 41 | 41 | 66 | 97 | 123 | 123 | 123 |
| XVK84 | Dashboard | 0 | 14 | 14 | 14 | 14 | 14 | 14 | 22 | 24 | 35 | 47 | 47 |
| XVK81 | Chassis | 0 | 0 | 13 | 19 | 19 | 19 | 33 | 36 | 50 | 50 | 66 | 66 |
| **Total** | **Total** | **39** | **68** | **146** | **189** | **297** | **345** | **454** | **587** | **699** | **837** | **849** | **802** |
| **Year 2023 - direct labour/ month** | | | | | | | | | | | | | |
| **ID** | **Designation** | **Jan.** | **Feb.** | **Mar.** | **Apr.** | **May.** | **Jun.** | **Jul.** | **Aug.** | **Sep.** | **Oct.** | **Nov.** | **Dec.** |
| XVK83 | Engine | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| XVK82 | Bumper | 88 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| XVK89 | Rear Wall | 60 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| XVK87&8 | Doors | 144 | 144 | 120 | 120 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| XVK85 | Roof | 178 | 178 | 178 | 148 | 148 | 119 | 119 | 119 | 119 | 119 | 119 | 119 |
| XVK86 | Front Wall | 113 | 103 | 103 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 |
| XVK84 | Dashboard | 118 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 282 | 423 |
| XVK81 | Chassis | 149 | 248 | 264 | 264 | 264 | 264 | 264 | 317 | 380 | 396 | 396 | 462 |
| **Total** | **Total** | **944** | **1074** | **1066** | **1016** | **992** | **963** | **963** | **1016** | **1078** | **1095** | **1189** | **1396** |

Table 5.8 continued

| Year 2024 - direct labour/ month | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ID** | **Designation** | **Jan.** | **Feb.** | **Mar.** | **Apr.** | **May.** | **Jun.** | **Jul.** | **Aug.** | **Sep.** | **Oct.** | **Nov.** | **Dec.** |
| XVK83 | Engine | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| XVK82 | Bumper | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| XVK89 | Rear Wall | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| XVK87&8 | Doors | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| XVK85 | Roof | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 |
| XVK86 | Front Wall | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 |
| XVK84 | Dashboard | 517 | 564 | 564 | 564 | 564 | 564 | 564 | 545 | 470 | 470 | 470 | 470 |
| XVK81 | Chassis | 594 | 726 | 924 | 1023 | 1056 | 1056 | 1056 | 1056 | 1056 | 990 | 990 | 990 |
| **Total** | **Total** | **1622** | **1801** | **1999** | **2098** | **2131** | **2131** | **2131** | **2112** | **2037** | **1971** | **1971** | **1971** |

## 5.5 Harness assembly sequence creation

In chapter 5.2 is defined the general production setup. Next step is to evaluate the wiring harness design which consists of functional modules with different order rate. Taking into consideration the assembly time of each individual module and order frequency, the harness is split to small kits which consists of 1-3 connectors and wires either between the connectors or wires with one end reaching to the connector part of the kit. Each wire has a dedicated storage place on assembly workstation. Kits are used to simplify the manufacturing process. Target of kit break is to reduce complexity of the assembly process of wiring harness with high variability. Figure 5.1 displays different type of kits. [29]

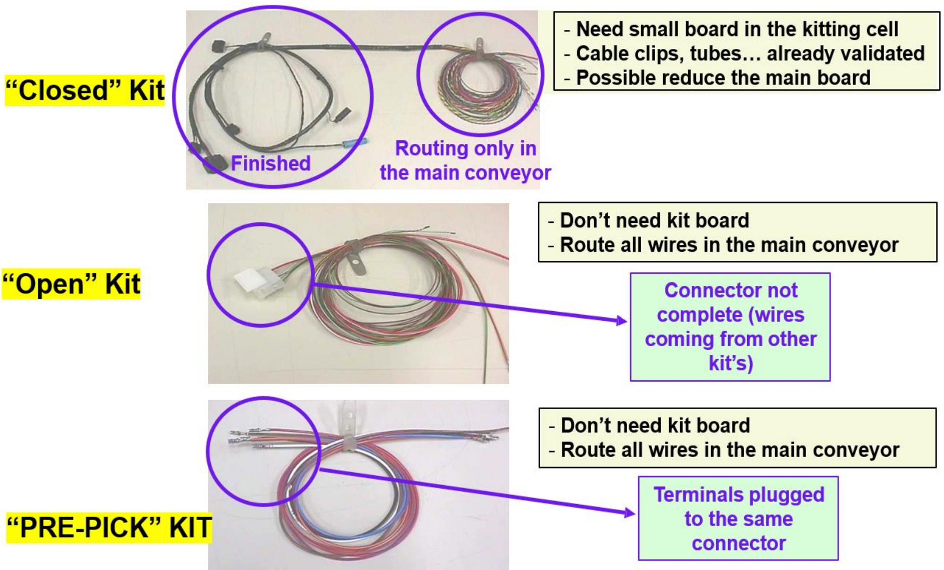


Figure 5.1 Wiring harness kits

When kit break is finalized on paper, sequence rules are created before starting to define final harness assembly sequence. General assembly sequence starts from highest complexity connectors. There are also kits which have no impact to other pre-assembled connectors and can be installed at any time in the process. [29]

Results of kit break analyse are visualized into detailed process flow diagrams for each product group which will be used as illustrated guidance for setting up the process on shop floor. The kit break data and assembly sequence are then loaded to "LAD" software an Oracle-database based program which is designated to show assembly operators step-by-step work instructions which are necessary for assembling products where each order differs from previous. Figure 5.2 displays an example of instruction step sheet displayed to assembly operator together with explanation of information fields. One product assembly instruction is divided between stations which refer to actual assembly station on conveyor line and between steps, which refer to individual assembly step done in one specific assembly station. Operator has either simplified keyboard or foot pedal, which is used to close the step display and switch to next one.

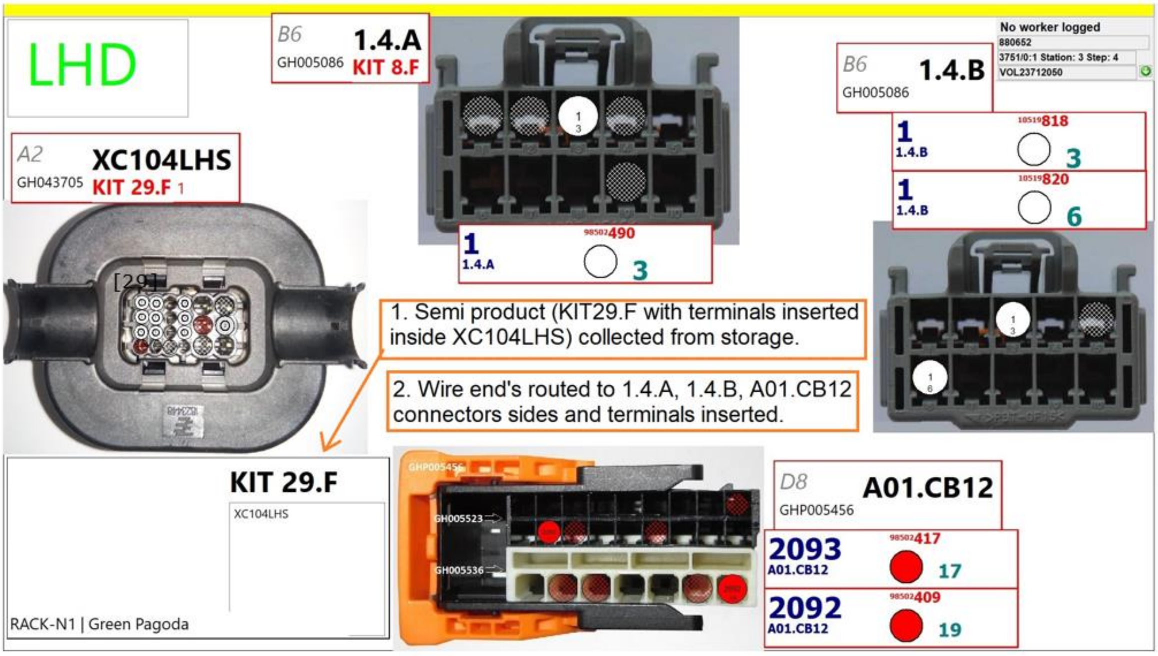


Figure 5.2 Digital assembly instruction displayed by LAD software

After initial kit break is created, it is possible to define detailed assembly procedure for each wiring harnesses and nominate workstation for each kit of group of kits. Also based on amount and complexity of different kits, it is evaluated if the kits are picked near the line by the final assembly operators or if the kits are collected by dedicated collection workers as a set for the product. The amount of kit assembly stations is not driven only by the needed labour time but also the storage capacity of each workstation.

The standard kit assembly workstation used in PKC Group factories can carry 64 wire positions. In case a kit belongs to function which are not often ordered but has high number of wires, there will be more than one kit station which will be simultaneously used by the same assembly operator. This means that the initial workstation count defined by labour time on Table 8 can change after kit break analyse. The outcome process flow for each SFTP wiring harness product after kit break definition are shown on appendix 6.

## 5.6 Ultrasonic welding equipment analysis

SFTP wiring harnesses consists of nodes where wires are connected to each other by using ultrasonic joining technology.

Ultrasonic joining is achieved by clamping the two pieces to be welded between an anvil and a vibrating probe or sonotrode. The vibration raises the temperature at the interface and produces the weld. A weld can be made in 0,005 second on thin wires. Spot welds and continuous seam welds are made with good reliability [28].

Ultrasonic weld nodes are covered with waterproof insulation layer which is heated over the splice node. Standard method for ultrasonic welding is to weld the wires together before final assembly conveyor line. Welded bundles are collected before assembly line and laid to the assembly board on the conveyor line. This method allows better utilization rate of the welding machine, but also requires extra handling by transporting the wires to welding station and later transporting to assembly line. Offline welded splice bundles are difficult to route through branch insulation tubes.

As a result of kit break analyse described in chapter 5.5.1, an alternative welding method – online welding - is evaluated for introduction in SFTP launch. Online welding means that ultrasonic welding machines together with heat shrink guns are installed on top of assembly conveyor and welding and shrinking operations are done on the rotating assembly conveyor simultaneously with the assembly process. This method is commonly used in passenger vehicles wiring harness manufacturing but is new for commercial vehicle harness manufacturing. Online welding allows to build bigger pre-assemblies and reduce time needed to handle the harness.

As a new process in PKC Group, it needs to be carefully validated during the pre-builds to avoid any failures during ramp-up period. For workstation calculation welding node points are counted from each harness drawing, combined with standard assembly time for individual operation and daily volumes. Standard times which are used for calculation are taken from time measurements conducted in a wiring harness company which has online welding process implemented for serial production. Following formula is used for calculation amount of welding machines:

$$Sc = \frac{DV \times WT \times N}{t_{avd}} \tag{5.6}$$

Where:

Sc is quantity of calculated value of workstations

DV is the daily volume of the product

WT is the ultrasonic welding or heat shrinking work time for one wiring harness in minutes

N is the quantity of weld nodes in wone harness

$t_{avd}$ is the available working time in minutes in a workday. 3 work shifts x 440 minutes per shift.

Based on formula 5.6, the amount of welding and heat shrinking machines are calculated. The results are shown in table 5.9 and table 5.10

Table 5.9 Ultrasonic welding workstation calculation

| **ID** | **Description** | **Stage** | **Nodes/ harness (pcs.)** | **Daily Volume (pcs.)** | **Welding (min.)** | **Stations calculated (pcs.)** | **Stations actual (pcs.)** |
|---|---|---|---|---|---|---|---|
| XVK83 | Engine High | Final | 2 | 378 | 0,8 | 0,46 | 1 |
| XVK83 | Engine Low | Final | 2 | 162 | 0,8 | 0,20 | |
| XVK86 | Roof High | Final | 1 | 378 | 0,8 | 0,23 | 1 |
| XVK86 | Roof Low | Final | 1 | 162 | 0,8 | 0,10 | |
| XVK85 | Front wall High | Final | 1 | 378 | 0,8 | 0,23 | 1 |
| XVK85 | Front wall Low | Final | 1 | 162 | 0,8 | 0,10 | |
| XVK84 | Dashboard Low LHD | Final | 16 | 146 | 0,5 | 0,88 | 4 |
| XVK84 | Dashboard High LHD | Final | 21 | 340 | 0,5 | 2,71 | |
| XVK84 | Dashboard Low RHD | Final | 16 | 16 | 0,5 | 0,10 | |
| XVK84 | Dashboard High RHD | Final | 21 | 38 | 0,5 | 0,30 | |
| XVK81 | Chassis Low | Final | 12 | 162 | 0,5 | 0,74 | 8 |
| XVK81 | Chassis High | Final | 15 | 378 | 0,5 | 2,15 | |
| XVK81 | Chassis Low | Pre | 4 | 162 | 0,5 | 0,25 | 2 |
| XVK81 | Chassis High | Pre | 6 | 378 | 0,5 | 0,86 | |
| XVK82 | Bumper High | Final | 1 | 378 | 0,8 | 0,23 | 1 |
| XVK82 | Bumper Low | Final | 1 | 162 | 0,8 | 0,10 | |

Table 5.10 Ultrasonic weld heat shrink workstation calculation

| ID | Description | Stage | Nodes/ harness (pcs.) | Daily Volume (pcs.) | Shrinking (min.) | Stations calculated (pcs.) | Stations actual (pcs.) |
|---|---|---|---|---|---|---|---|
| XVK84 | Dashboard Low LHD | Final | 12 | 146 | 0,8 | 1,06 | 6 |
| XVK84 | Dashboard High LHD | Final | 17 | 340 | 0,8 | 3,51 | |
| XVK84 | Dashboard Low RHD | Final | 12 | 16 | 0,8 | 0,12 | |
| XVK84 | Dashboard High RHD | Final | 17 | 38 | 0,8 | 0,39 | |
| XVK81 | Chassis Low | Final | 12 | 162 | 0,8 | 1,18 | 8 |
| XVK81 | Chassis High | Final | 15 | 378 | 0,8 | 3,44 | |
| XVK81 | Chassis Low | Pre | 4 | 162 | 0,8 | 0,39 | 2 |
| XVK81 | Chassis High | Pre | 6 | 378 | 0,8 | 1,37 | |
| XVK82 | Bumper High | Final | 1 | 378 | 0,5 | 0,14 | 1 |
| XVK82 | Bumper Low | Final | 1 | 162 | 0,5 | 0,06 | |
| XVK81 | Chassis Low | Final | 12 | 162 | 0,8 | 1,18 | 8 |
| XVK81 | Chassis High | Final | 15 | 378 | 0,8 | 3,44 | |
| XVK81 | Chassis Low | Pre | 4 | 162 | 0,8 | 0,39 | 2 |
| XVK81 | Chassis High | Pre | 6 | 378 | 0,8 | 1,37 | |
| XVK82 | Bumper High | Final | 1 | 378 | 0,5 | 0,14 | 1 |
| XVK82 | Bumper Low | Final | 1 | 162 | 0,5 | 0,06 | |

## 5.7 Final assembly equipment design for chassis harness

Wiring harness, which is installed to SFTP truck chassis, weights approximately 45 kilograms depending on the order content and can reach up to 20 meters from length. Harness is covered with closed or zipper isolation tubes on the full range and consists average 160 circuits. Combining weight, dimensions, and wide range of variable length parts in the harness, the manufacturing workstation requires custom design which allows access to product from all sides and follows the geometry how the product is installed on the end location. Chassis wiring harness is routed through both side members of truck chassis with a pass via second cross member. This means an H-shape main geometry for the product.

As an initial task, 1:1 scale assembly drawing is prepared to define the dimensions of one workstation. As defined on Table 11 and Table 12, the conveyor line must be equipped with 3 heat shrinking devices and 3 ultrasonic welders. Google SketchUp software is used to draw initial design proposal for the conveyor line. Figure 5.3 and 5.4 displays schematics for workstation together with rail system carrying welding machines and shrinking machines. Purple parts on the assembly board are movable templates for the variable length areas of the product.

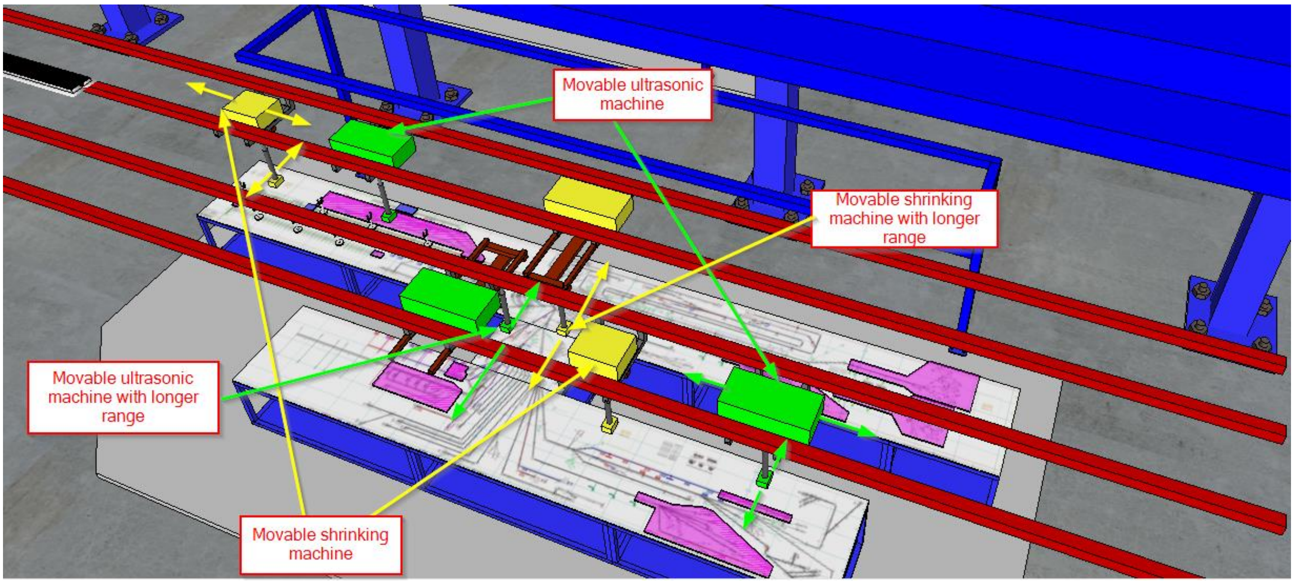


Figure 5.3 SFTP XVK81 chassis harness assembly station on rotary conveyor

Assembly operators are standing on the platform and moving together with conveyor. Using platform allows access to the H-shape board from each side and prevents accidents which can occur working closely of large size moving objects.

Figure 5.4 SFTP XVK81 chassis harness assembly conveyor top view

## 5.8 Cutting equipment analysis

Cutting process is different depending on wire diameter. Wires with cross section area less than 6mm$^2$ are possible to cut and crimp on a cutting station. Wires with cross section more than 6mm$^2$ are possible only to cut and crimping is done on semi-automatic crimping presses.

Cutting stations for less than 6mm$^2$ wires are divided into two types:

Cut and crimp stations – machines which cut wires and add non-sealed terminals to wire ends;

Cut, seal and crimp stations – machines which cut wires, add insulation seals on wire ends and crimp terminals over sealed wire ends. Cut, seal and crimp stations can be used also for non-sealed terminal crimping.

Although cutting machines have speed and output characteristics defined by machine suppliers, these values are not usable when calculating quantity for the machines for high mix wiring harness production setup, because machine maker output values reflect the technical output on ideal conditions. These values don't consider product mix, changeover times, machine stoppages due maintenance, material lacks or other organizational reasons. Hourly output rates can vary due to cutting batch size, wire length and wire type. Batch sizes vary due because varying production volumes of different end products. For cost calculations are used standard work phase times which consider changeover time and batch size (Table 5.1). Standard times can be useful only with scenario that the cutting machines are used for specific products only. Actual machine set up in wire harness plant doesn't reflect scenario where each group of cutting machines are dedicated to one specific product, rather the machines are used to cut wires for all product groups which are manufactured on a factory.

Besides SFTP products, manufacturing unit in Serbia produces wiring harnesses for several other customer programs, therefore batch sizes and set up times set for SFTP products with standard BOL are not equal to the average times for cutting wires for all products in the factory. To evaluate machine demand for a production unit, average historical output should be measured and extrapolated to future projects. Machine quantities are calculated by using following formula:

$$MQ = \frac{DV \times CD \times NS}{SO} \quad (5.9)$$

Where:

MQ is machine quantity

DV is the daily volume of the product

CD is wire cuts per day per product

NS is the quantity of shifts per day

SO is cuts per one machine per shift

Using SFTP products cutting data export from product database and applying formula 5.9, <6mm$^2$ wire cutting machine quantities are shown on table 5.11 and >6mm$^2$ wire cutting machine quantities are shown on table 5.12

Table 5.11 <6mm$^2$ wire cutting machine calculation for SFTP program

| **Wire type** | **Cuts per day (pcs.)** | **Nr. of shifts** | **Shift output (pcs.)** | **Machines (pcs.)** | **Machines, rounded (pcs.)** |
|---|---|---|---|---|---|
| Not sealed | 146100 | 3 | 4500 | 10,82 | 11,00 |
| Sealed | 20900 | 3 | 4500 | 1,55 | 2,00 |
| | | | | **Total machine need (pcs.):** | **13,00** |

Table 5.12 >6mm$^2$ wire cutting machine calculation for SFTP program

| **Wire type** | **Cuts per day (pcs.)** | **Nr. of shifts** | **Shift output (pcs.)** | **Machines (pcs.)** |
|---|---|---|---|---|
| Single | 9660 | 3 | 1200 | 2,68 |
| Multicore | 2100 | 3 | 1200 | 0,58 |
| Ready-twisted | 18900 | 3 | 1600 | 3,94 |
| | | | **Total machines (pcs.)** | 7,20 |
| | | | **Total machines, rounded (pcs.)** | 8,00 |

Cutting and crimping machines for sealed <6mm$^2$ wires require changeable applicator for each seal which belongs to product range. Table 5.13 displays range of seals together with daily volume and machine quantities. Since seal applicators are components of sealed cutting machine, same shift and output values apply. The applied formula is similar for formula 5.9 but instead cuts per machine and day, crimps per machine and day are the input values

Table 5.13 Seal applicator calculation for SFTP program

| Seal code | Crimps per day(pcs.) | Nr of shifts | Shift output (pcs.) | Tool need (pcs.) | Tool need, rounded (pcs.) |
|---|---|---|---|---|---|
| GWS005054 | 51600 | 3 | 4500 | 3,82 | 4,00 |
| GWS005402 | 10500 | 3 | 4500 | 0,78 | 1,00 |
| not identified | 5400 | 3 | 4500 | 0,40 | 1,00 |
| GWS005354 | 4800 | 3 | 4500 | 0,36 | 1,00 |
| GWS005183 | 4500 | 3 | 4500 | 0,33 | 1,00 |
| GWS005204 | 2100 | 3 | 4500 | 0,16 | 1,00 |
| GWS005183 | 1800 | 3 | 4500 | 0,13 | 1,00 |
| GWS005197 | 1200 | 3 | 4500 | 0,09 | 1,00 |
| GWS005127 | 900 | 3 | 4500 | 0,07 | 1,00 |
| GWS015454 | 900 | 3 | 4500 | 0,07 | 1,00 |
| GWS066833 | 600 | 3 | 4500 | 0,04 | 1,00 |
| 07911630053 | 300 | 3 | 4500 | 0,02 | 1,00 |
| | | | | **Total machine need, rounded (pcs.)** | **15,00** |

Wiring harnesses include branch insulation in areas where is chafing risk or risks for environmental hazards such as high temperatures or contact with chemicals. Branch insulations are either PVC tubes or corrugated tubes. These tubes are supplied to PKC Group on reels and cut to required length on dedicated tube cutting machines. Table 5.14 displays volumes, average machine output and machine quantities for tube cutting devices

Table 5.14 Tube cutting machine calculation for SFTP program

| Insulation type | Cuts per day (pcs.) | Nr of shifts | Shift output (pcs.) | Machines (pcs.) | Machines, rounded (pcs.) |
|---|---|---|---|---|---|
| PVC | 31200 | 3 | 2500 | 4,16 | 5,00 |
| Corrugated | 14100 | 3 | 3000 | 1,57 | 2,00 |
| | | | | **Total machine need (pcs):** | **7,00** |

## 5.9 Crimping equipment calculation

Wire ends are crimped to terminal ends with press benches which apply force to push terminal collar against wire. Crimping presses can be integrated to cutting machines in case wires cross section is below $6mm^2$. For larger cross section wires or multicore products, benchtop crimping machines are in use. In case if more than one wire is crimped together to one terminal, benchtop machines are needed for crimping. Benchtop crimping machines are also used if wires need to pass through very small diameter protection tube. This process is called retro crimping as the crimping operation is done after the final assembly of the wires to wiring harness.

For sealed terminals are used benchtop presses which are equipped with seal feeder and applicator. Regular benchtop presses apply sudden force impulse to apply the terminal to wire. Terminals have two pair of collar wings from which one pair is pressed around wire insulation and second pair is pressed around wire core. In case wire cross section exceeds 10 $mm^2$, terminals with tubular main body are in use. As the press force need to be applied equally around the tubular main body, pneumatic type presses are used, which push crimp jaws around the terminal. Applied forces are bigger than for regular terminal, therefore the duration of pressing the jaws take more time. Instead of pushing the terminal walls together, stable force for longer period is applied.

Although terminal crimping has dedicated labour time defined in bill-of-labour, historical average shift output is more reliable metric to use in crimping tools calculation. Machine quantities are calculated by using following formula:

$$MQ = \frac{DV \times CrD \times NS}{SO} \quad (5.10)$$

Where:
MQ is machine quantity
DV is the daily volume of the product
CrD is terminal cuts per day per product
NS is the quantity of shifts per day
SO is crimps per one machine per shift

Using formula 5.10, crimping station quantities are calculated and displayed in table 5.15

Table 5.15 Crimping station calculation for SFTP program

| Crimping type | Crimps per day (pcs.) | Nr of shifts | Shift output (pcs.) | Machines (pcs.) | Machines, rounded (pcs.) |
|---|---|---|---|---|---|
| Regular, not sealed | 145500 | 3 | 3000 | 16,17 | 16,00 |
| Pneumatic, not sealed | 5100 | 3 | 500 | 3,40 | 3,00 |
| Regular, sealed | 29100 | 3 | 3000 | 3,23 | 3,00 |
| Retro fitment, not sealed | 8100 | 3 | 800 | 3,38 | 3,00 |

Setting up wire processing area also requires investment of shop floor furniture and tools for quality controls (measuring tools), equipment for process control and work instructions (computer sets), equipment for wire ends preparing (wire stripping machines) Each benchtop crimp station has a standard set of auxiliary equipment; therefore, the needed quantities are driven by the quantity of crimp presses. In addition to dimensional process controls (checking whether the terminal dimensions meet the ranges defined by the terminal manufacturer), the applied crimp force is monitored with build in crimp force analyser and validated by using pull force testers. Pull force test is needed to apply to one termination from each crimping job batch. One pull force tester can be shared between 4 crimping workstations, with lesser tools queues my occur on the pull force monitoring stations.  List of auxiliary tools with quantities are displayed on Table 5.16

Table 5.16 Auxiliary processing equipment for SFTP program processing area

| **Auxiliary equipment name** | **Quantity (pcs.)** |
|---|---|
| Computer set with monitor | 25 |
| Wired barcode scanner | 25 |
| Monitor holder | 25 |
| Micrometer | 25 |
| Micrometer stand | 25 |
| Micrometer connecting cable, USB | 25 |
| Measuring caliper | 25 |
| Wire stripping machine | 25 |
| Workbench | 25 |
| Chair | 25 |
| Pull force tester | 6 |

Crimping presses (whether stand-alone or integrated to automatic cutting station) require specific application set for each different type of wire terminal. Applicator set consists of main body and punch anvils which are displayed on Figure 5.5. To calculate number of crimping applicators, it is necessary to import product data (wire positions together with terminal codes of each wire ends) from cutting database, then add annual projected volumes for each product and divide with average shift output which is dependent of the fastening method (regular crimping or pneumatic crimping). Total need for SFTP project is 257 crimp applicators.

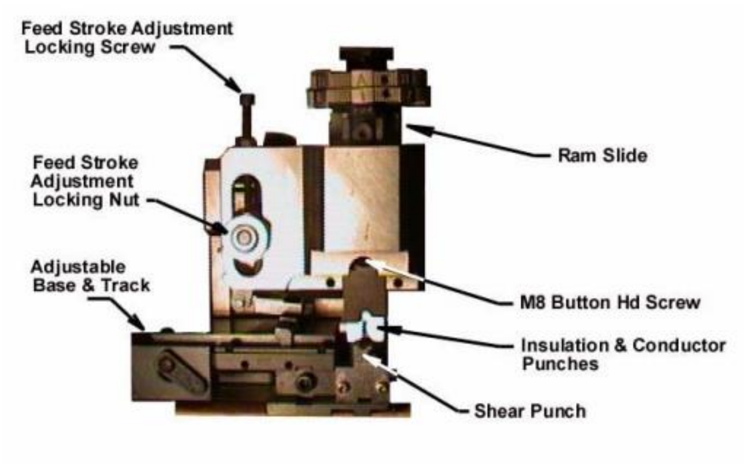


Figure 5.5 Crimping applicator [30]

## 5.10 Testing Equipment analysis

Wiring harnesses are required to pass electrical connectivity test before reaching to customer. Such testing is needed to avoid missing or short connections on the electric system of vehicles or other equipment. Connectivity is tested with low voltage (12 volts) current, using connectivity analysers designed for wiring harness testing together with software which guides the operators and logs each connection test result. Besides connectivity test, the test benches also ensure that terminals are locked into connector housings and correct connector housings are in use. Each connector housing has a test counterpart which is designed as a mating part with the intent to avoid usage of wrong components, also in case of seals, a vacuum check is done to ensure proper tightness of the sealed part. In case the connector housing includes locking or covers, presence of these items will also be checked. Final electric test stations also include colour sensors for verifying presence of spot tapes and test counterparts for passive components such as tie clips, manifolds, rubber grommets and brackets.

For complex harnesses which include more than 20 passive components, separate test stations are used only for passive component presence check. Test benches have a connection with the ERP system to read in the product configuration and communicate test result back to ERP system. In case passed test result is not transferred from test bench to ERP system, it is not possible to print out package label and add the product to invoice and waybill of the carrier. Figure 5.6 shows typical test counterparts with main components.

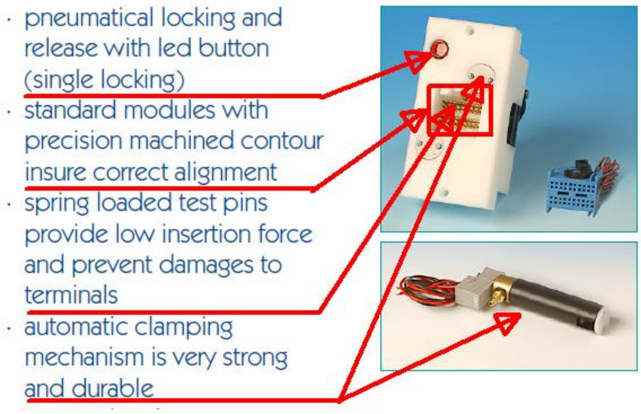


Figure 5.6 Test counterpart [31]

Work time spent of connectivity and presence check of SFTP harnesses are described in bill of labour. For each component in harness is nominated time needed for adding the component to test counterpart, running the test, removing the component from the table. Depending on size of harnesses and production volumes, a test bench can be either dedicated for testing one product or a range of products.

In case of SFTP program, the daily production volumes are in a range which requires more than one test bench for each product, therefore combining products to universal test benches is not reasonable as it will increase the cost of testing units and impact the production flow negatively. Dashboard XVK84 wiring harness meets the criteria of more than 20 passive components, therefore for this product will be designed separate test stations for connectors connectivity and presence test and separate test stations for passive components presence and dimensional check.

As a lesson learned from previous launches, intermediate circuit presence checks for XVK81 chassis, and XVK84 dashboard harness pre-assemblies is introduced. Complex harnesses XVK81, XVK84 and XVK86 are considered to have two operators per workstation to reduce capital need and efficiency of operators as the weight of complex harnesses is better handled by two workers.

Amount of test equipment is calculated according following formula:

$$Sc = \frac{DV \times TT_{std \times} Pr}{t_{avd}} \tag{5.11}$$

Where:

Sc is quantity of calculated value of workstations

DV is the daily volume of the product

$TT_{std}$ is the testing work time for one wiring harness in minutes
Pr is the targeted productivity compared to $TT_{std}$ immediately after ramp-up
$t_{avd}$ is the available working time in minutes in a workday. 3 work shifts x 440 minutes per shift.

Using formula 5.11, test station quantities are calculated and displayed in table 5.17

Table 5.17 Harness test equipment for SFTP program

| ID | Description | Stage | Daily Volume (pcs.) | Testing (min.) | Target Efficiency % | Worker /station | Stations calculated (pcs.) | Stations actual (pcs.) |
|---|---|---|---|---|---|---|---|---|
| XVK84 | Dashboard Low LHD | Final | 146 | 12,0 | 70% | 2 | 0,95 | 5 |
| XVK84 | Dashboard High LHD | Final | 340 | 19,0 | 70% | 2 | 3,50 | |
| XVK84 | Dashboard Low RHD | Final | 16 | 12,0 | 70% | 2 | 0,11 | 1 |
| XVK84 | Dashboard High RHD | Final | 38 | 19,0 | 70% | 2 | 0,39 | |
| XVK81 | Chassis Low | Final | 162 | 15,0 | 50% | 2 | 1,84 | 7 |
| XVK81 | Chassis High | Final | 378 | 15,0 | 50% | 2 | 4,30 | |
| XVK82 | Bumper High | Final | 378 | 3,4 | 70% | 1 | 1,39 | 2 |
| XVK82 | Bumper Low | Final | 162 | 3,0 | 70% | 1 | 0,53 | |
| XVK83 | Engine High | Final | 378 | 4,4 | 70% | 1 | 1,80 | 3 |
| XVK83 | Engine Low | Final | 162 | 4,1 | 70% | 1 | 0,72 | |
| XVK85 | Front wall High | Final | 378 | 5,3 | 70% | 1 | 2,17 | 3 |
| XVK85 | Front wall Low | Final | 162 | 3,8 | 70% | 1 | 0,67 | |
| XVK86 | Roof High | Final | 378 | 8,0 | 70% | 2 | 1,64 | 4 |
| XVK86 | Roof Low | Final | 162 | 6,1 | 70% | 2 | 0,53 | |
| XVK87 | Driver Door High | Final | 378 | 3,3 | 70% | 1 | 1,33 | 4 |
| XVK87 | Driver Door Low | Final | 162 | 3,3 | 70% | 1 | 0,57 | |
| XVK88 | Pass. Door High | Final | 378 | 3,3 | 70% | 1 | 1,33 | |
| XVK88 | Pass. Door Low | Final | 162 | 3,3 | 70% | 1 | 0,57 | |
| XVK89 | Rear wall High | Final | 378 | 3,5 | 70% | 1 | 1,43 | 2 |
| XVK89 | Rear wall Low | Final | 162 | 2,2 | 70% | 1 | 0,39 | |
| XVK84 | Dashboard Low & High | Pre | 540 | 4,0 | 85% | 2 | 0,96 | 1 |
| XVK84 | Dashboard Low & High | Pre | 540 | 4,0 | 85% | 2 | 0,96 | 1 |
| XVK84 | Dashboard Low & High | Pre | 540 | 4,0 | 85% | 2 | 0,96 | 1 |
| XVK84 | Dashboard Low & High | Pre | 540 | 4,0 | 85% | 2 | 0,96 | 1 |
| XVK81 | Chassis Low & High | Pre | 540 | 4,0 | 85% | 2 | 0,96 | 3 |
| XVK81 | Chassis Low & High | Pre | 540 | 4,0 | 85% | 2 | 0,96 | |
| XVK81 | Chassis Low & High | Pre | 540 | 4,0 | 85% | 2 | 0,96 | |
| XVK84 | Dashboard LHD | Post | 486 | 9,0 | 85% | 1 | 1,95 | 2 |
| XVK84 | Dashboard RHD | Post | 54 | 9,0 | 85% | 1 | 0,43 | 1 |

## 5.11 Floorspace analysis and shop floor layout

Floor space is calculated based on the needed tooling defined in chapter 5.6. Equipment described on tooling list has provided to plant CAD engineer together with measurements for equipment which is custom designed for SFTP wiring harnesses (such as test tables, conveyor lines). Together with equipment list is provided process flowcharts for each individual product group as described in chapter 5.5. The equipment together with necessary pathways between assembly lines are drawn to empty factory floor plan drawing. Table 5.18 summarizes floor space need required for each product manufacturing area together with common processing area.

Table 5.18 Floor space for SFTP products

| ID | Product | Area (m2) |
|---|---|---|
| XVK83 | Engine | 850 |
| XVK82 | Bumper | 450 |
| XVK89 | Rear Wall | 350 |
| XVK87/88 | Door | 800 |
| XVK86 | Roof | 1200 |
| XVK85 | Front Wall | 300 |
| XVK84 | Dashboard | 2500 |
| XVK81 | Chassis | 5000 |
| All products | Processing | 1050 |
| | **Total:** | **12500** |

To fit in additional 12 500 m2 of manufacturing area to PKC Group premises in Serbia, several production units are transferred to other sites with available floorspace. As the production transfers do not ensure enough released shop floor, additional manufacturing unit is developed in city of Pozarevac, 60km distance from main production unit in Pozarevac, Serbia.  Plant layout drawings based on the analysis performed on chapters 5.2-5.10 are shown on appendix 7 (PKC Serbia Smederevo factory) and on appendix 8 (PKC Serbia Pozarevac factory).

# 6. IMPROVEMENTS OF IMPLEMENTATION PROJECT

## 6.1 Implementing and performing process validations build audits

As a lesson learned from previous launches, process audit check sheet was put together by the project team which gives a numerical rating for each aspect of the readiness of launch, covering manufacturing, environmental health and safety, human resources, engineering, maintenance, supply chain and general workplace organization (6S) covering 67 evaluation points to be observed. Example of check sheet is shown on appendix 9. SFTP launch was first product launch where such rating was used. The process validation is done by cross functional team, led by plant operations project leader, and conducted by NPI process engineer, quality engineer, EHS engineer and production manager.

The initial attempts to conduct the evaluation where not successful, mainly because the questions where not completely understandable for the auditors and the rating criteria was not clear. Therefore, a series of review meetings were held to explain the questionnaire and agree the expectations of level of production readiness during each process validation build.

First question point which needed to clarify was how to check and evaluate tooling availability, it was not understood for the auditors if they need evaluate availability of the full tooling needed for starting the serial production or if they need evaluate availability of tooling to conduct the planned build.

Second question point was rating the degree of completion of the tools on the shop floor, mainly test benches and assembly boards which include more than hundred jigs to fixate the housings. During production launch preparation, these workstations were not fully completed as for some assembly jigs were not timely available material samples to design the parts and with some components (especially ring terminals for XVK81 chassis harness), were ongoing consultation with the customer about which component to use as these were not clearly stated on the received documentation. Part of the team members preferred and absolute approach where a workstation can’t be considered available for use when it misses even one component and tool availability therefore should get therefore a red rating. Part of the team preferred a relative approach that missing less than 5% of designed parts can be acceptable in case they have temporary replacements (probe testing on test benches or universal metal holder on assembly workstations).

Third question point was rating the output and productivity. As the excepted productivity of the first ramp-up week (with completely set up production area) will be between 5-10 % of the final productivity requirement, the project team raise a question if a productivity assumption for pre-build event should be established. On the other hand, targeting only 5 % of productivity would be setting the target too low for less complex harnesses and give a wrong impression to production operators. On the other hand, for complex harnesses such has dashboard and chassis harness, a 5 % percent productivity during first build attempt can be considered good.

Also measuring productivity during pre-build events is often not achievable as the production process is often put on hold to various issues (such as missing material, additional consulting with engineers etc). Therefore, was agreed that only the output quantity wise should be evaluated (for example build event duration is one week with 50 pieces of harnesses to produce and 10% difference is acceptable) and main metric how to evaluate the assembly sequence is to measure the balance between workstations on the conveyor lines. This means at on a conveyor line, clean work time (non-value-added time and stoppages removed) will be measured. The measured times are not compared with standard times but are compared with the times between each station. If the time on each station remains in 5 % range, the line balance is considered good, in case the gap is bigger, the work sequence needs to be revised and redesigned.

The initial procedure initiated that accepted result is 70% "green" results, however after revising the procedure, it was agreed that different acceptable results should be targeted, depending on the phase of preparation. Therefore, for first trial builds (first of tool build) a lower target result of minimum 50% was agreed as during these builds the focus should be on evaluating the assembly board and ability to produce a product which matching the customer specification. Next build events – process validation builds – a target result of minimum 70% was agreed as these builds should reflect availability of suitable series production intent process for making the products. At the same time, goal of the process validation build was to find out any weaknesses, validate theorical assumptions and identify any potential improvements to process, therefore a perfect result of such builds can't be expected. Final build events before starting ramp-up – interim PPAP build – a target result of minimum 85% was agreed as these builds are the last ones before starting ramp-up, therefore the gap between ideal situation can be only minimal, so only fine tuning of tools and processes can be acceptable to implement after the build audit and before starting the serial production. Table 6.1 presents the results of process validation builds conducted until April 2022. All the rating results meet the accepted minimum requirement which is evidence that the resources added to the project and quality of project planning and preparation has been successful.

Table 6.1 Process validation build results for SFTP production launch

| ID and Designation | Build | Timing | Planned Harness Quantity | Produced Harness Quantity | Findings to be corrected before next build | Build rating | Acceptable limit |
|---|---|---|---|---|---|---|---|
| XVK81 Chassis | FOT1 | WK06 2022 | 10 | 10 | Instruction issues (missing information, missing variable length, wrong information), Missing tool for crimping Design issue (terminal 50mm for wires 16+25), Manual definition for tubes (length + diameter), Sub assembling difficulties (routing needs improvement), Electrical tester is not complete (missing 25 counterparts). | 60% | 50% |
| XVK82 Bumper | FOT1 | WK34 2021 | 10 | 9 | Wrong information work instructions, wrong direction on branch on assembly board. | 67% | 50% |
| XVK82 Bumper | PV1 | WK44 2021 | 50 | 50 | Difficulties identify variable length tubes, work instruction not clear. | 73% | 70% |
| XVK82 Bumper | PV2 | WK06 2022 | 50 | 50 | Step 5 on sub assembly conveyor measured time over 5min (takt time 2min) tubes assembly, average measured time around 3min, Conveyor Step 3 is empty. Wrong insulation tube lengths. | 75% | 70% |
| XVK82 Bumper | PV3 | WK12 2022 | 50 | 50 | Delay of build start due to missing cut wires, KIT preparation out of balance (most critical stations G and E), Conveyor line out of balance. | 76% | 70% |
| XVK83 Engine | FOT1 | WK42 2021 | 10 | 8 | Wrong information work instructions, short cut wires, wrong position on middle weld node. | 66% | 50% |
| XVK83 Engine | PV1 | WK48 2021 | 50 | 45 | Wrong information work instructions, short cut wires, wrong position of weld node, wrong holder on assembly board, missing assembly information for insulation tubes. | 70% | 70% |

Table 6.1 Continued

| ID and Designation | Build | Timing | Planned Harness Quantity | Produced Harness Quantity | Findings to be corrected before next build | Build rating | Acceptable limit |
|---|---|---|---|---|---|---|---|
| XVK83 Engine | PV2 | WK05 2022 | 50 | 50 | Wrong position on middle weld node, missing assembly information for insulation tubes, long cut wires due wrong theoretical wirelengths, work instructions are not correct, Electrical tester is not complete (missing 3 counterparts). | 71% | 70% |
| XVK83 Engine | PV3 | WK10 2022 | 50 | 50 | Wrong position on middle weld node, missing assembly information for insulation tube. Insulation tube too small to fit., Counter parts for ring terminals are not ready (3 are installed of 4), Line Balance - out of range for 2nd step (23 minutes instead of 5 minutes), Quality check time excessive, Tester number 2 and number 3 are delivered to shop floor but not set up. | 75% | 70% |
| XVK84 Dashboard | FOT1 | WK02 2022 | 5 | 5 | Wrong information on work instructions, kit break not understandable by operators, operators not able to add sub-assembled part to final assembly board, wrong dimension of holder jig on final assembly board, wrong dimension between tie clips, missing components to complete harness. | 50% | 50% |
| XVK85 Front Wall | FOT1 | WK10 2022 | 10 | 10 | 1 day in delay due to missing assembly board. Wrong cut wire lengths, Missing Electrical Test station. Wrong information on work instruction. | 68% | 50% |

Tabled 6.1 Continued

| ID and Designation | Build | Timing | Planned Harness Quantity | Produced Harness Quantity | Findings to be corrected before next build | Build rating | Acceptable limit |
|---|---|---|---|---|---|---|---|
| XVK86 Roof | FOT1 | WK11 2022 | 10 | 10 | Delay of start of build due to missing marked connector housings, Delay of build start due to missing cut wires, wrong information work instructions. | 70% | 50% |
| XVK87&88 Door | FOT1 | WK09 2022 | 10+10 | 10+10 | Test table programming wrong. | 66% | 50% |
| XVK89 Rear Wall | FOT1 | WK45 2021 | 10 | 10 | Pre-assembly and taping method not feasible for serial production requirement. | 63% | 50% |
| XVK89 Rear Wall | PV1 | WK48 2021 | 50 | 40 | Work instructions conflicting with assembly board product data. | 71% | 70% |
| XVK89 Rear Wall | PV2 | WK07 2022 | 50 | 50 | Missing proper tools for rubber grommet assembly. Tangled wires received from central cutting area. Shop floor layout doesn't reflect process flow chart. Lay-out to adjust according to process flow. Taping machine not ergonomically to use. Wrong position of test counter parts. Wrong length of cut wires. | 71% | 70% |
| XVK89 Rear Wall | PV3 | WK12 2022 | 50 | 50 | Delay of build start due to missing cut wires. Kits received from pre-assembly area in tangled condition. Ultrasonic welding online not proper set up (wires tangled and with wrong cut lengths). Test bench not set up for RHD harness, Tool missing for rubber grommet assembly. | 73% | 70% |

Table 6.1 presents summary of findings during the build. Besides the summary and check sheet, all individual observations are recorded and transferred to corrective action plans with the aim to fix all the findings latest before the next pre-build event. The corrective action plans creation and follow-up is led by operating project leader. The ratings of build events show a positive trend as clear evidence that the launch preparation processes towards the goal of complete readiness for series production. Such detailed approach compared to traffic light rating with subjective summarizing gives bigger transparency for the project preparation status and allows the project team to focus on the most problematic topics on an organized matter. A selection of images of the most complex products workstations with products from the FOT builds are shown under the graphics section.

## 6.2 Reducing ramp-up duration for Bumper, Engine and Rear Wall wiring harness

Chapter 6.1 gives overview of process validation builds performed until 12$^{th}$ week of year 2022. For three products which are scheduled to ramp-up first (XVK82 Engine, XVK83 Front Bumper and XVK89 Rear Wall), the main outcome of corrective actions listed in table 6.1 are reflected by the production output per shift performed during the latest performed process validation build. When comparing the shift output results with the output targets set for the production teams during the planned ramp-up (appendix 4) and taking the median initially set ramp-up curve as benchmark, it is visible that production teams have achieved already the output which was planned for 5$^{th}$ week for Front Bumper and Engine harness and for 3$^{rd}$ week for the Rear Wall harness. Table 6.2 is showing the pre-build results and the respective ramp-up production week using median ramp-up curve for given product shown on appendix 4

Table 6.2 Pre-build shift output comparison with ramp-up plan for Front Bumper, Engine and Rear Wall wiring harnesses [32]

| **ID** | **Designation** | **Production date** | **Output/shift (pcs.)** | **Initial median ramp-up curve (weeks)** | **Week of median ramp-up curve with achieved output** |
|---|---|---|---|---|---|
| XVK82 | Front Bumper | 22.03.2022 | 35 | 11 | 5$^{th}$ |
| XVK83 | Engine | 11.03.2022 | 31 | 11 | 5$^{th}$ |
| XVK89 | Rear Wall | 24.03.2022 | 45 | 9 | 3$^{rd}$ |

Based on that comparison, it can be concluded that the ramp-up curves can be reduced as many weeks as the production team is ahead of the planned ramp-up plan. For Front

Bumper and Engine harnesses, the new proposal for ramp-up curve would be 11 – 5 = 6 weeks or 30 days. For Rear Wall, the new proposal would be 9 – 3 = 6 weeks or 30 days. The initial ramp-up plan had different duration ramp-up curves for different production teams starting to produce the same harness, as most case the first production teams have more downtime due to late production adjustments. As on the given case, most production adjustments have done between the process validation builds and before the ramp-up, equal duration ramp-up curves can be applied for each team producing the same wiring harness. Using the same methodology as described in chapter 5.3, new ramp-up plans are created for observed three product groups. The resulted plans are shown on appendix 10.

For calculating the benefit of reducing the ramp-up curve duration, the quantities of planned output of the initial and reduced scenario should be compared. As the products are customer specific with short JIT order signal, all the products produced during ramp-up until the penultimate week, must be initially scrapped. Therefore, the savings of reducing the ramp-up time can be directly measured by finding out how many products less need to be produced and scrapped during the ramp-up. Table 6.3 summarizes production quantities for given products shown in appendix 4 and appendix 10 together with evaluating the cost reduction via reducing the amount of produced products. The product price includes both labour and material costs. The total saving from reducing the ramp-up production plan for three validated products is 121 957, 30 euros.

Table 6.3 Savings from reducing ramp-up production plan for Bumper, Engine and Rear Wall harness

| **ID** | **Designation** | **Total production plan according to initial ramp-up plan (pcs.)** | **Total production plan according to proposed ramp-up plan (pcs.)** | **Reduction of products to be scrapped (pcs.)** | **Unit price (EUR)** | **Savings per product (EUR)** |
|---|---|---|---|---|---|---|
| XVK82 | Front Bumper | 20515 | 18795 | 1720 | 26,03 | 44 771,60 |
| XVK83 | Engine | 19645 | 18675 | 970 | 57,38 | 55 658,60 |
| XVK89 | Rear Wall | 21635 | 20105 | 1530 | 14,07 | 21 527,10 |
| | | | | | **Savings (EUR)** | **121 957,30** |

As the evaluated three products represents approximately 13 percent of the total price of one SFTP truck wiring harness truck set and have the shortest initial ramp-up plan, applying similar approach for the rest of products can bring significant reduction of the overall ramp-up costs. However as there is missing evidence about which output can be achieved for the rest of products, such reduction value is not possible to calculate as part of the thesis.

## 6.3 Creating responsibility matrix for project team

Figure 10 presents organization chart of project team. Each project team member tasks and responsibilities are described on their individual job descriptions which usually focused on their functional duties and doesn’t explain their participation and role in new product implementation projects. The job descriptions are not publicly available for all employees participating on project and can include tasks which are not required during a product launch. The Program Management procedure and New Product Implementation procedure described on sections 3.5 and 3.6 give a generic overview of tasks needed to conduct during a product launch but do not describe all tasks and responsibilities which are necessary for a product implementation project. As an outcome, not all project team members and program managers were not completely aware of share of responsibilities and related communication chain. Such situation was creating tension on project meetings as the tasks and boundaries are not clearly defined, several actions are either on delay or some cases not done. Project managers and NPI leaders need to spend a lot of effort to convince team members and their direct managers about tasks required. Also, the project leaders need to conduct specialist level employee tasks such as raw material availability checks, capacity calculations or start micromanaging the project directly with specialists who report to their functional managers who should be responsible for their respective function’s performance in the project.

For overcoming mentioned organizational problem in the launch management, a systematic approach for describing tasks and responsibilities has been proposed to implement. The RASIC-Chart or matrix is an integrated view of who is involved and in which role across all project activities or process steps from start to end of a project. The roles are described in a rather generic way. Starting from the first process down to the last line the project manager needs to discuss and agree with the team members, who is doing what, means who is Responsible, Approving, Supporting, Informed and Consulting. It is preferred, that only one role can be responsible for a task or process. Other roles can support, consult, or be informed. Another important aspect is the active involvement of the decision makers. This role needs to be shown in the RASIC. Typically, a decision maker´s role is to approve tasks, decide in case of multiple options how to conduct a task, to receive information such as reports and support other team members with information, resources and advise. [33]

As the new product implementation project includes repetitive tasks from one project to another, a standard RASIC chart can be composed which can be used for the SFTP project launch and later for other product launches in the company or in general for launching customer specific high scale wiring harness production in automotive industry.

The designations in the RASIC approach are defined as follows:

- Responsible: The person who is ultimately responsible for delivering the project and/or task successfully;
- Accountable: The person who has ultimate accountability and approval authority, they review and assure quality and are the person to whom "R" is accountable;
- Supporting: The team or persons supporting the actual work with resources, time, or other material benefit. They are committed to tasks completion;
- Informed: Those who provide input and must be informed of results or actions taken but are not involved in final decision-making;
- Consulted: Those who provide valuable input into product design or establish quality review criteria. Their buy-in is important for successful implementation. [34]

Following guidelines should be considered when describing RASIC chart:

- Only one Accountable function. Two or more of accountable functions create risk for conflict and confusion;
- More than two responsible functions for a task means duplication of work;
- No responsible for a task means there is a gap to be filled or the task is not needed;
- Same person can be responsible and accountable;
- If there are too many support functions per task, there may be insufficient capacity. [34]

Based on the RASIC method description and product launch phases and task descriptions described on sections 3.5 and 3.6, all tasks needed for product launch were listed together with functions participating in the product launch as described on organizational chart on Figure 4.4. Combining project team members with their area of responsibilities and expertise, a RASIC chart for PKC Group product launch has been prepared as a part of the thesis. The chart with designation abbreviations is shown on Table 6.4.

Table 6.4 RASIC chart for new product implementation in PKC Group

| Phase | ID | Task Name | SALES ENGINEERING | | | | OPERATIONS | | | | | SUPPLY CHAIN | | | | IT | HR | AE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Program Management | Product&Data Management | Costing | Account Management | Manufacturing Engineering | New Product Implementation | Quality | Planning | Production | Logistics | Sourcing | Direct Purchasing | Indirect Purchasing | Information Techonology | Human Resources | Advanced Engineering |
| Program Planning | 1 | Work with Business to Define Launch Metrics Targets | R | S | | A | | C | | | I | I | | | | | | |
| | 2 | Conduct Design Review | A | R | S | I | C | C | C | | C | | | | | | | |
| | 3 | Provide Customer Timing Plan (Key Milestones from Customer) | R | S | I | A | I | I | I | I | I | I | I | I | I | I | I | |
| | 4 | Create General Timing plan - booking timeslot for key activities | R/A | S | C | I | C | S | I | I | C | I | I | C | I | I | I | |
| | 5 | Negotiate Timing Changes with customer | R | S | I | A | I | C | I | C | C | I | I | C | I | I | I | |
| | 6 | Publish Harness Parts List | A | R | S | C | I | I | I | I | I | | | | | | | |
| | 7 | Publish Sales and Capacity Planning Volumes | A | C | S | R | I | I | I | I | I | | | | | | | |
| | 8 | Determine Plant Assignment | R/A | I | I | I | I | S | I | I | I | I | I | I | I | I | I | |
| | 9 | Analysis of Design Prints | I | R/A | S | I | S | S | C | | | | | | | | | |
| | 10 | Creation of standard BOM's, BOL's, cutting and crimping data | I | A | R/S | | I | C | | | | | C | | | | | |
| | 11 | Define floor space required | I | | | I | S | R/A | | | C | C | | | | | | |
| | 12 | Design plant lay-out | I | | | | R/S | A | I | | C | C | | | | I | | |
| | 13 | Initial Fixture Projections (Formboard scheduling) | I | I | | | S | R/A | I | | I | | | | C | | | |
| | 14 | Initial Equipment Projections (Machine & tools) | I | I | | I | S | R/A | | | I | | | | I | | | |
| | 15 | Assembly Board and Test Board Design | I | I | | | R/S | A | C | | C | | | | | | | |
| | 16 | Definition and design of Pre-Assembly Station | I | I | | | R/S | A | C | | C | | | | | | | |
| | 17 | Identify Packaging requirements | I | S | I | I | S | R | | C | | A | | | I | | | |
| | 18 | Initial Direct People Projections | I | I | | I | S | R/A | C | | C | C | | | | | | |
| | 19 | Initial Capital Projections and Budget Availability | R | | | A | S | R | C | | C | C | | | | | | |
| | 20 | Initiate RAS (CAPEX) Forms Online - Manufacturing Equipment | I | I | | | S | A | | | I | | | | R | | | |
| | 21 | Initiate RAS (CAPEX) Forms Online - Support/Infrastructure | A | | | | | | S | | S | S | | | R | S | S | |
| | 22 | Follow-up on Capital RAS (CAPEX) Approval- Manufacturing Equipment | A | | | I | I | R | I | | I | I | | | S | I | | |
| | 23 | Follow-up on Capital RAS (CAPEX) Approval - Infrastructure | A | | | I | | S | I | | I | I | | | S | I | I | |
| | 24 | Approve Changes Against Capital Project (Capex Tracking ) | R | | | A | I | S | C | | C | C | | | | | | |
| | 25 | Complete Capital Project Reviews (payback) P&L | S | | | R/A | S | R/S | C | | C | C | | | | C | | |
| | 26 | Follow-up Customer Reimbursable Funds until Recovered | I | | | R/A | S | R | | | | | | | S | | | |
| | 27 | Complete Capital Project Closure Process | S | | | R/A | | S | | | | | | | S | | | |
| Procedures and Management Activities | 28 | Create and Implement Launch Scorecards Project status report | R/A | I | I | I | I | S | C | C | C | C | | C | | C | C | |
| | 29 | Complete and Distribute Scorecards on regular basis | R/A | I | I | I | I | C | I | I | I | I | I | I | I | I | I | |
| | 30 | Perform Risk Assessment Audit and escalate Program Risks to Management | R/A | I | I | I | I | S | C | C | C | C | I | C | I | C | C | |
| | 31 | Operations review with the customer | R/A | C | I | S | C | R/S | C | C | C | C | I | C | C | I | I | |
| | 32 | Lead regular Program Meetings | R/A | C | C | C | C | S | C | C | S | C | C | C | C | C | C | |
| | 33 | Lead Engineering Process Reviews and Launch Readiness Reviews (internal process audit) | A | I | I | I | S | R | S | I | S | C | I | I | I | I | I | |
| | 34 | Maintain Tooling Order Tracking Document | I | | | S | R/S | R/A | I | | I | I | | | S | I | | |
| | 35 | Maintain Tooling & Equipment Summary (inventory, capacities, etc.) | I | | | I | R/S | R/A | I | | I | I | | | S | I | | |
| | 36 | Lead Customer Launch Readiness Reviews (customer process audit) | R/A | S | | I | S | S | R/S | C | S | S | | | | | | |
| | 37 | Customer Related APQP | R/A | S | | I | S | S | S | C | C | S | | C | | | | |
| | 38 | Lead Lessons Learned Process by program | R/A | C | C | I | S | S | S | C | C | C | C | C | C | C | C | |
| | 39 | Facilitate Communication Between Commercial Engineering & Manufacturing | A | R | I | I | I | S | I | I | I | I | I | I | I | I | I | |
| | 40 | Coordinate Customer Visits to Manufacturing Plants | R/A | S | I | I | S | R/S | S | C | C | C | I | C | C | I | I | |
| | 41 | Development Process FMEA. | I | C | | | S | S | R/A | | C | C | | | | | | |
| | 42 | Define and map the process flow chart | I | I | I | I | S | R | A | C | C | C | | | | | | |
| | 43 | Define Standardized Work | I | I | | | S | R | C | | C | C | | | | | | |

Table 6.4 Continued

| Phase | ID | Task Name | SALES ENGINEERING | | | | OPERATIONS | | | | | SUPPLY CHAIN | | | | IT | HR | AE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Program Management | Product&Data Management | Costing | Account Management | Manufacturing Engineering | New Product Implementation | Quality | Planning | Production | Logistics | Sourcing | Direct Purchasing | Indirect Purchasing | Information Techonology | Human Resources | Advanced Engineering |
| Prototype and Pre-Production | 44 | Coordinate Prototype Build Events | A | R | | C | S | S | S | | S | S | S | S | S | | S | |
| | 45 | Resolve Prototype scheduling Issues | R/A | S | | I | C | S | I | C | C | I | | C | | | | |
| | 46 | Provide information on special attention on components | | R/A | S | | I | I | I | I | I | I | C | C | | | | |
| | 47 | Monitor Raw Materials Status and Elevate Issues (during launch) | A | C | | I | C | C | I | R | I | I | C | S | | | | |
| | 48 | Create/Provide Formboard Drawing | I | I | | | R/S | A | C | | I | | | | | | | |
| | 49 | Provide Customer Specifications | A | R | I | | C | C | C | | I | I | | | | | | |
| | 50 | Track new components for quote | I | S | I | A | I | I | | | | | R | I | | | | |
| | 51 | Track samples for new components (for tooling samples) | I | C | C | | R/S | A | I | S | S | C | | S | I | | | |
| | 52 | Lead New Mfg. Process Development | I | C | C | I | R/S | R/A | S | | S | C | | | | | | |
| | 53 | Initial Plant Layout Concept | I | I | | I | R/S | R/A | C | | C | C | | | | | | |
| | 54 | Perform Manufacturing Feasibility Studies for new materials | I | A | | | S | R | S | | C | | C | | | | | |
| | 55 | Determine processing methods | | I | I | | R/S | A | C | | C | | | | | | | |
| | 56 | Create mfg. BOM and BOL. Determine cutting specifications / production COP data | | I | I | | R/S | A | C | | C | | | | | | | |
| | 57 | Coordinate Crimp Validation and Positive Results | | I | I | | R | A | S | | S | | | | | | | |
| | 58 | Cutting capacity studies | I | I | | I | R/S | R/A | C | | C | C | | | | | | |
| | 59 | Confirm Tooling Requirements | I | I | | I | R/S | R/A | C | | C | C | | | | | | |
| | 60 | Order Tooling & Equipment Requirements | I | | | I | R/S | R/A | I | | I | I | | | S | I | | |
| | 61 | Build and release of Assy Board and Electric Test Station design | I | | | I | R/S | R/A | S | | C | I | | | S | | | |
| | 62 | Schedule and Manage Master Sample Reviews and Document Issue | I | I | | | S | S | R/A | | C | | | | | | | |
| | 63 | Ensure Building of Sample Harnesses (for assembly table, testing table release) | I | | | | R | A | C | | S | | | | | | | |
| | 64 | Receive, Distribute, maintain, and Track Deviations | I | R/A | S | I | S | S | I | C | C | | | C | | | | |
| | 65 | Excess/obsolete material review | A | | | I | | | | R | S | | | S | | | | |
| Launch and Production | 66 | PPAP Plan for Initial Program PPAP (Dates, ) | A | S | | I | S | R | R | C | C | | | | | | | |
| | 67 | Set up and validate EDI connections | S | C | | I | | I | | C | I | I | | C | | R/A | | |
| | 68 | IT systems development and modification for program requirements | I | C | | I | C | S | C | C | C | C | | | | R/A | | |
| | 69 | Set production parameters (divisions, setitem, messageID, lotsizes, summary periods) | I | | | I | C | S | | R/A | S | C | | | | | | |
| | 70 | Present PPAP Plan To Org/Customer | A | S | | I | C | S | R | I | I | I | | | | | | |
| | 71 | Develop Harness Parts List For PPAP with quanitites | C | R | | C | S | S | C | I | I | I | | | | | | |
| | 72 | Re-confirm tooling and equipment | I | I | | I | R/S | R/A | C | | C | C | | | S | | | |
| | 73 | Component PPAP Complete Documentation | I | C | | | | | A | | | | R/S | | | | | |
| | 74 | Get Ramp-Up / Balance Out Plans from Customer | S | I | | R/A | C | C | I | C | C | I | | I | | | | |
| | 75 | Initial Ramp-Up Plans | I | I | | C | C | R/A | I | C | C | I | | I | | | C | |
| | 76 | Firm Ramp-Up Plans (Internal) | I | I | | C | C | R/A | I | S | C | I | | I | | | C | |
| | 77 | Mass production material forecast according lead times | C | | | C | S | S | | R | I | I | | A | | | | |
| | 78 | Elaborate production plans | I | I | | C | C | S | I | R | A | I | | I | | | C | |
| | 79 | Expedite Capacity counterparts, formboards and applicators | I | | | I | R/S | R/A | I | | I | I | | | S | I | | |

Table 6.4 Continued

| Phase | ID | Task Name | SALES ENGINEERING: Program Management | Product&Data Management | Costing | Account Management | OPERATIONS: Manufacturing Engineering | New Product Implementation | Quality | Planning | Production | SUPPLY CHAIN: Logistics | Sourcing | Direct Purchasing | Indirect Purchasing | IT: Information Techonology | HR: Human Resources | AE: Advanced Engineering |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Launch and Production | 80 | Coordinate Assy board and Test Station design review with Plant | I | I | | | R | A | S | | C | | | | | | | |
| | 81 | Elaboration of capacity studies | I | I | | I | R/S | R/A | C | I | C | C | | | | | I | |
| | 82 | Capacity Equipment in Place | I | I | | I | R/S | R/A | C | | C | C | | | S | | | |
| | 83 | Determine best Build sequence | I | I | | | R/S | A | C | | C | | | | | | | |
| | 84 | Resident Engineers in Place | A | I | I | R | I | I | I | I | I | I | | | | | S | |
| | 85 | Validation of Assembly on Production Environment | I | I | | I | R/S | R/A | C | I | S | C | | | | | I | |
| | 86 | Line Balance | I | I | | | R/S | A | C | | C | | | | | | | |
| | 87 | Lead development for Run@Rate Plan | I | I | | C | S | R/A | I | C | C | I | | I | | | | |
| | 88 | Present Run@Rate Plan to Org/Customer | S | S | | I | C | R/A | I | I | I | I | | I | | | | |
| | 89 | Coordinate R@R and Act as "Monitor" as Required | I | | | | S | A | C | C | R | | | | | | C | |
| | 90 | Customer On-site Support Plan | R/A | I | | C | C | I | C | I | S | I | | | | | S | |
| | 91 | Hiring & Training Plan for Indirect / Direct People | I | | | C | S | S | S | | S | S | | | | | R/A | |
| | 92 | Schedule and lead line release process | I | I | | C | S | R/A | S | C | S | I | | I | | | | |
| | 93 | Track Production vs. Ramp-Up Plan | I | I | | I | I | A | I | S | R | I | | | | | | |
| New Technologies | 94 | Process development mapping. | I | I | | | | R/A | C | | C | | | | | | | S |
| | 95 | Research and development of new production technologies | I | I | | | | A | C | | C | | | | S | S | | R/S |
| | 96 | Share the information to all relevant parties, product managers etc. | I | I | I | I | S | R/A | S | | S | I | | | | I | | S |
| | 97 | Global info sharing with production sites | I | I | I | I | S | S | I | | I | I | | | | I | | R/A |
| | 98 | Global Best practice communication | I | I | I | I | S | S | I | | I | I | | | | I | | R/A |

The initial RASIC chart has been presented to PKC Group program management team leader and regional functional managers to collect their feedback for the proposed distribution of responsibilities and explain the tasks and the decision logic behind the proposed chart. The outcome will be submitted to be part of updated company's project management procedure in the quality management system database and will be used as a guideline for the upcoming product launches in PKC Group.

## 6.4 Improving communication and management engagement

Project team leading a product launch is required to report the status of project to PKC Group top management on a regular basis. Prior the SFTP product launch, a monthly program management reporting has established summarized for all ongoing product launches in company. For major launches, gate reviews were held 4 times during the launch (after pre-planning phase, after prototype phase, after launch preparation phase and during ramp-up phase). Large scale product launches are prepared during two-year period, which means that a gate review was held some cases only twice per year. This means that the management can collect detail feedback about project status and occurring problems (such as lack of resources, delays of planned timeline, overspending) with a significant delay and loosing valuable time to react and implement countermeasures in case the project team needs management support.

For SFTP launch, the company's program management team has established bi-weekly reviews with top management to ensure timely feedback about project status which allows the management to be involved on the ongoing launch activities. Such reviews allow escalate occurring issues real-time and solve them on time. A standardized reporting sheet focusing on the "3M's" – material, men, machine – has been established. As an outcome, management approvals to speed up hiring additional white-collar resources or approving capital expenditure requests have been received on a faster pace compared to previous product launches which has allowed to keep the project on schedule.

Also driven by the complexity of SFTP products launch, the industrialisation process status reporting lead by NPI Manager has been redesigned. Besides the monthly reporting described on chapter 3.6, a weekly reporting was established. NPI manager defines major NPI projects together with regional operations management and reports status weekly in NPI Weekly report which is reviewed weekly with VP Operations and shared with PKC CEO and PKC EU&SA WH president. Increasing the frequency to report project status to management team increases the quality of decision making both NPI team and management

## 6.5 Updating PKC Group's quality management system

PKC Group is a tier 1 supplier in automotive industry which means that the company must follow same international standards for the automotive industry as their OEM customers. Therefore, the company's all manufacturing units and regional centres are certified according IATF 16949:16 standard. This standard defines the requirements for a quality management system for organizations in the automotive industry, including automotive production, service and/or accessory parts organizations, aiming to harmonize the different assessment and certification systems in the global automotive supply chain [35].

Quality Management System in PKC Group is set up as an online document database which gives general description and aims of each department in the organization, procedure descriptions and technical quality requirements. Although besides documents in QMS, each function in the company has various training materials, procedure descriptions and other guiding documents in use, such documentation is not binding until the document structure is standardized, approved by regional quality manager, and added to the quality management system. A procedure description and technical quality requirement in QMS can be considered as a standard in the company.

As a result of launch process improvements, the procedures for New Product Implementation and Project Management have been updated to ensure more clear understanding to the company how to perform product launches. The responsibility matrix (RASIC chart) described in chapter 6.2 has been considered as a standard way of sharing responsibilities between the functions and added to the program management procedure.  New Product Implementation procedure has been updated with standard for ramp-up plan creation and criteria described in chapter 5.3 and appendix 3, standard for process validation build described in chapter 6.1 and standard for communication procedure described in chapter 6.3.

Chapter 5.5 describes how a wiring harness diagram is analysed for creating assembly sequence and how the assembly instructions are visualised. Such task is one of the most critical for the later successful serial production as the overall productivity of the personnel is directly related how the assembly work steps are defined and balanced compared to each other. Assembly sequence creation and visualisation has been always a matter of individual decision making of the process engineers assigned to the task, means that the shop floor set up and work instructions have been not standardized between the production plants or even between different production units in the same plant. During the preparation for SFTP product launch, the project team held a workshop to agree the basic metric for making the kit break and splitting the work content between pre-assembly stations and final assembly stations. These metrics describe the maximum and minimum size of pre-assemblies and how big share of total assembly work time should be consumed on the final assembly conveyor lines. Based on the agreed metrics and visualisation standard for SFTP program, five new procedures were created and added to PKC quality management system:

- Manufacturing Engineering: Criteria for sequence, layout, workload balance;
- Manufacturing Engineering: Kit Break Criteria;
- Manufacturing Engineering: Preparation of KIT break file;
- Manufacturing Engineering: Data preparation for line balancing;
- Manufacturing Engineering: Visualization of wiring harness assembly instructions using LAD software.

# 7. SUMMARY

This thesis describes implementation of new wiring harness production together with finding a better way how to conduct a product launch in a large-scale commercial vehicle wiring harness manufacturing company – PKC Group. Precise and thorough planning is key to achieve a desired outcome for each project, especially when the project teams include tens of shareholders, and the company needs to run several production launches in parallel. Using a significant scale launch – Strategic Future Truck Program wiring harnesses – as an example, the existing launch procedures are described together with improvements done based on the lessons learned on the ongoing and previous product launches.

The thesis starts with an overview of the company, its history, customer base, market situation and range of operations. Next the manufacturing process of wiring harnesses for commercial vehicles is described together with the existing procedures for program management and new product implementation process.

Next section gives overview of Daimler Truck AG Strategic Future Truck Program wiring harness launch project which has been as a case study example in the thesis main part. Product range planned supply chain setup and timing of main launch milestones are described. List of lessons learned from previous product launches are mapped, which become the basis of decision making for the launch preparation and a source for improvements for the product launch procedure.

Third part of thesis focuses on the product data analysis and manufacturing concept definition. As wiring harness manufacturing requires a lot of manual work force and manual operations, dividing the assembly process to small steps are crucial for successful production setup. Manufacturing concept together with planned work times for each production step are used as the basis for labour and equipment need calculation together with evaluation for shop floor area and designing the shop floor layout. Furthermore, process flow charts for each product manufacturing are created and strategy and planning for ramping up the products are conducted.

Final part of the thesis describes the implemented improvements to the launch procedure and the status of the product launch performance as of the time the thesis has been finalized. The success of product launch preparation is evaluated via auditing internal production runs which are intended to trial the processes and tooling defined on the third part of thesis. During the product launch following procedural improvements have been proposed and described and added to PKC Group's quality management system:

- Responsibility matrix for the product launch project team using RASIC method;
- Communication method for the product launch team;
- Standard for creating ramp-up plans;
- Standard criteria for assembly sequence and balancing workload;
- Standard for dividing complex wiring harnesses to pre-assemblies;
- Standard for creating documentation describing pre-assembled sub-products;
- Standard for data preparation for assembly work instructions;
- Standard of visualization of wiring harness assembly instructions using PKC Group LAD software.

For three products which are planned to ramp-up first, production output from process validation builds were compared with planned production output during the ramp-up. It was evident that the production teams had achieved a level of output which was initially planned to achieve on the 3rd or 5th week during the ramp-up. As the products manufactured during the ramp-up were not for sale and were planned to scrap, performing shorter ramp-up with less products manufactured during ramp-up period will save 121 957 € of labour and material cost.

As the observed product launch project was on the middle of the preparation and validation phase during writing the thesis, it was not possible to conclude if the result – a product launched on time and on budget – will be met. However, the analyse of trial builds is showing positive trend and the new project evaluation methods give more data points for adjusting the manufacturing processes before start of serial production. The standards and methods for implementing large scale wiring harness production can be applicable on the other companies in the industry and can give a positive impact of cost and time control of production launches.

# 8. KOKKUVÕTE

Käesolev diplomitöö kirjeldab uue toote juurutamist koos parendusettepanekutega suuremahulise tarbesõidukite juhtmeköidiste tootmise lansseerimiseks ettevõttes PKC Group. Täpne ja põhjalik planeerimine on iga uue tootmisprojekti edukaks juurutamiseks võtmetähtsusega, eriti kui projekti meeskond koosneb paljudest osapooltest ja ettevõtte peab juurutama mitmeid uusi tootmisprojekte paralleelselt. Näidiskaasuseks on kasutatud Daimler Truck AG Strategic Future Truck Program juhtmeköidiste tootmise alustamise projekti, mis on oma mahult üks suurimaid ettevõtte ajaloos. Kirjeldatud on olemasolevad toote juurutamise protseduurid koos eelmistest projektidest saadud kogemuse ja parimate praktikate rakendamisega.

Diplomitöö esimene osa annab ülevaate ettevõtte ajaloost, tootevalikust, klientidest, turusituatsioonist ja finantsnäitajatest. Järgmisena kirjeldatakse tarbesõidukite juhtmeköidiste valmistamise tootmisprotsessi ning ettevõtte olemasolevat projektijuhtimise ja uue toote juurutamise protseduuri.

Töö järgmine osa annab detailse ülevaate Strategic Future Truck Program juhtmeköidiste tootmise juurutamise projektist, mida kasutatakse näidisena kogu töö vältel. Kirjeldatakse tooteid, tarneahelat ja põhiliste ettevalmistustegevuste tähtaegasid. Varasemalt ettevõttes tehtud juurutamisprojektide positiivsed ja negatiivsed õppetunnid on kaardistatud. Seda infot kasutatakse otsuste tegemiseks ja parenduste lähtekohaks, et parendada uue toote juurutamise protseduuri.

Kolmas töö osa keskendub tooteid kirjeldavate andmete analüüsile ja tootmiskontseptsiooni defineerimisele. Juhtmeköidiste tootmine nõuab suures mahus käsitööd ja tööjõudu, seetõttu on eduka tootmisstuktuuri aluseks väga oluline jagada kõik tööetapid sobilikus mahu ja järjekorraga alltööetappideks. Tootmiskontseptsioon koos planeeritud tööetappideks kuluva ajaga on aluseks tööjõu ja tootmistehnilise ressursi arvutamiseks. Igale tootele on loodud tootmisprotsessi voodiagramm koos strateegia ja plaaniga tootmismahtude järkjärguliseks tõstmiseks kuni lõppeesmärgi saavutamiseni.

Viimases töö osas kirjeldatakse juurutamisprotsessi sisse viidud parendusi ja vaatluse all oleva tootejuurutusprojekti teostust diplomitöö koostamise lõpu hetkel. Tootejuurutamise protsessi edukust on hinnatud läbi tootmise katseseeriate auditeerimise. Katseseeriate eesmärk on valideerida planeeritud tootmisprotsesside, seadmete ja tööriistade sobilikkust ning leida parendust vajavaid kitsaskohti tootmisprotsessis enne seeriatootmisega alustamist. Vaatluse all oleva tootmise juurutamise projektiga seoses on loodud mitmeid protseduurilisi uuendusi ning ettevõtte kvaliteedi juhtimissüsteem on täiendatud järgnevate protseduurikirjeldustega:

- Tootejuurutamise projektimeeskonna vastutusmaatriks kasutades RASIC metodoloogiat;
- Projektimeeskonna teabeedastuse reeglid;
- Tootmismahtude suurendamise planeerimine;
- Standard juhtmeköidiste koostamisjärjekorra loomiseks ja töövoo tasakaalustamiseks;
- Standard töömahuka juhtmeköidise poolkoostudeks jagamiseks;
- Standard töömahuka juhtmeköidise poolkoostude dokumenteerimiseks;
- Standard tööjuhenditeks vajalike andmete ettevalmistamiseks;
- Standard juhtmeköidiste koostamisjuhendite visualiseerimiseks kasutades PKC Group LAD tarkvara

Katsetootmise tulemusi kolmele esimesena lansseeritavale tootele võrreldi planeeritud tulemustega lansseerimisperioodi ajal. Ilmnes, et tootmismeeskonnad on saavutanud võimekuse toota kogustes, milleni oli esialgselt planeeritud jõuda kolmandal kuni viiendal tootmise lansseerimise nädalal. Lansseerimisperioodil toodetavaid juhtmeköidised ei ole võimalik müüa ja neist saaksid tootmisjäätmed, seetõttu on lansseerimisperioodi vähendamisega saavutatud materjalide ja tööjõu sääst väärtuses 121 957 eurot.

Kuna vaatlusalune tootejuurutusprojekt oli diplomitöö kirjutamise ajal planeerimise ja valideerimise etapis, ei olnud võimalik hinnata lõpptulemust ehk tootmise lansseerimist etteantud aja ja eelarve piirides. Siiski, katsetootmispartiide auditeerimistulemuste trend on olnud positiivne ja uued tootmisprotsessi hindamise reeglid annavad arvukalt sisendit, mis võimaldab tootmisprotsesse reguleerida ja parendada enne seeriatootmisega alustamist. Töös käsitletud standardeid ja meetodeid suuremahuliste juhtmeköidiste tootmisprojektide lansseerimiseks on võimalik kasutada ka teistes ettevõttetes kes tegutsevad samas valdkonnas.

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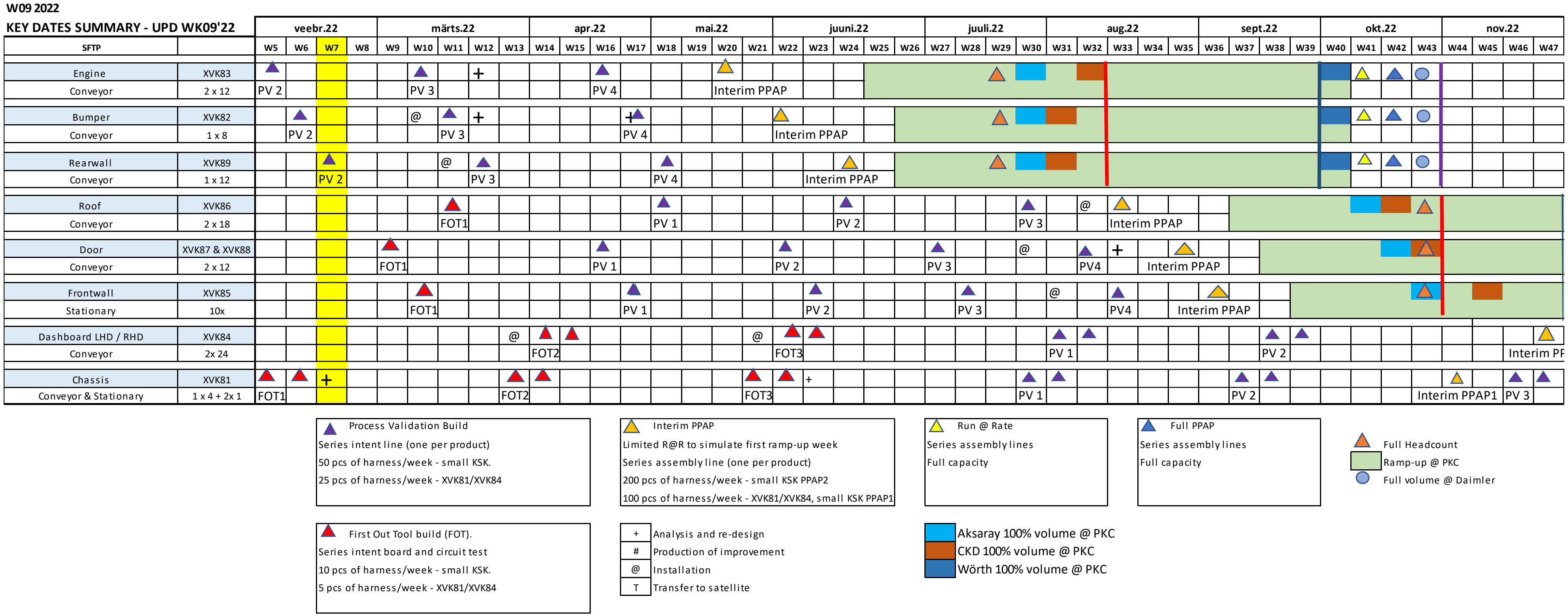
# APPENDICES

# Appendix 1: Pre-build schedule



## Appendix 2: Average product set sub work phases

| Description3 | Qty | Time(min)/truck |
|---|---:|---:|
| CRIMPING, PNEUMATIC, 1 wire/terminal | **13,00** | **4,00** |
| CRIMPING, SEMI-AUTOMATIC, 1 wire/terminal | 286,00 | 18,88 |
| CRIMPING, SEMI-AUTOMATIC, 2 wires/terminal | 3,00 | 0,40 |
| Quality measurement, manual crimping | 27,00 | 1,49 |
| Set up time, manual crimping | 27,00 | 0,27 |
| ULTRASONIC WELDING, 2 wires | 2,00 | 0,53 |
| ULTRASONIC WELDING, 3 wires | 11,00 | 4,11 |
| ULTRASONIC WELDING, 4 wires | 2,00 | 0,97 |
| ULTRASONIC WELDING, 5 wires | 2,00 | 1,19 |
| ULTRASONIC WELDING, 6 wires | 4,00 | 2,82 |
| ULTRASONIC WELDING, 7 wires | 1,00 | 0,81 |
| ULTRASONIC WELDING, 8 wires | 2,00 | 1,85 |
| ULTRASONIC WELDING, 9 wires | 1,00 | 1,03 |
| **CRIMPING TERMINALS Total:** | **381,00** | **38,34** |
| CONDUCTOR/WIRE stripping | 292,00 | 22,48 |
| CUTTING, BRAIDED SLEEVE, average length mm | 2,93 | 0,30 |
| CUTTING, CORRUGATED TUBE, average length mm | 38,43 | 3,81 |
| CUTTING, PVC-tube from spool, average length mm | 23,09 | 2,28 |
| CUTTING, SPECIAL TUBE/HOSE, average length mm | 7,06 | 0,69 |
| CUTTING, ZIPPER TUBE, average length mm | 12,72 | 1,25 |
| GLUEING hot glue | 13,00 | 8,58 |
| LABEL printing | 10,00 | 0,32 |
| Manual twisting included to harness | 5,00 | 22,68 |
| MARKING, housing | 229,00 | 15,11 |
| MCC cable jacket stripping | 4,12 | 11,78 |
| Shrink tube thread, shrink over splice/UW | 25,00 | 8,25 |
| SHRINK TUBE, thread shrink to terminal | 11,00 | 3,63 |
| **HANDLING Total:** | **673,34** | **101,17** |
| Change of cutting job, multicore cable | 6,00 | 0,55 |
| MACHINE CUTTING, multicore cable | 49,00 | 9,52 |
| Quality measurement, multicore cable | 6,00 | 0,03 |
| **MACHINECUTTING, MULTICORE CABLE Total:** | **61,00** | **10,09** |
| Change of cutting job, seal wires | 22,00 | 3,84 |
| MACHINE CUTTING, seal wires, average length mm | 170,00 | 8,01 |
| Quality measurement, seal wires | 7,00 | 2,34 |
| **MACHINECUTTING, SEAL WIRES Total:** | **199,00** | **14,19** |
| Change of cutting job, single wires | 7,00 | 1,47 |
| MACHINE CUTTING, single wire, average length mm | 421,00 | 12,11 |
| Quality measurement, single wires | 7,00 | 2,51 |
| **MACHINECUTTING, SINGLE WIRES Total:** | **435,00** | **16,09** |
|  | **1749,34** | **179,89** |

| Description3 | Qty | Time(min)/truck |
|---|---|---|
| ADAPTER assembling, normal | 51,00 | 12,34 |
| BLIND seal to housing, manually | 40,00 | 5,28 |
| BOX TO TABLE | 1,00 | 0,55 |
| BRACKET | 5,00 | 0,66 |
| CABLE TIE, fixing tie | 74,00 | 16,28 |
| CABLE TIE, manually | 80,00 | 9,68 |
| CABLES TO ASSEMBLY TABLE, average length mm | 121,68 | 8,50 |
| CAP to housing | 5,00 | 0,44 |
| CARRIER assembling | 23,00 | 8,35 |
| CLIP assembling | 4,00 | 0,44 |
| COVER | 6,00 | 2,18 |
| COVER TO HOUSING | 7,00 | 2,54 |
| FUSE BOX to table | 1,00 | 0,20 |
| HARNESS remove from TABLE | 9,00 | 2,38 |
| HOUSING to assembly table | 230,00 | 12,65 |
| LABEL assembling | 10,00 | 1,32 |
| LOCKING closing in housing | 59,00 | 5,84 |
| LOCKING to housing | 29,00 | 2,87 |
| NUT assembling | 2,00 | 0,55 |
| PART ASSEMBLY | 6,00 | 2,18 |
| READY MADE CABLE, to assembly table, avL mm | 10,00 | 1,89 |
| RING | 4,00 | 0,62 |
| RUBBER GROMMET, assembly | 5,00 | 2,53 |
| SHRINK TUBE, thread and shrink to wire, avL mm | 2,00 | 0,66 |
| SLEEVE to FLANGE | 0,20 | 0,02 |
| TAPING, branches | 122,00 | 87,95 |
| TAPING, lengthwise | 10,00 | 7,05 |
| TAPING, loosely wound tape, average length mm | 35,00 | 5,63 |
| Taping, mark tape/spot tape | 125,00 | 19,25 |
| TAPING, tightly wound tape, average length mm | 89,00 | 39,47 |
| TAPING, to hose end | 40,00 | 18,48 |
| TERMINALS TO HOUSING, normal | 1034,00 | 85,34 |
| TERMINALS TO HOUSING, terminal + seal | 270,00 | 29,70 |
| T-MANIFOLD/BRANCH/JOINT assembling, normal | 6,00 | 1,32 |
| TUBING, BRAIDED SLEEVE, average length mm | 2,93 | 1,46 |
| TUBING, CORRUGATED TUBE, average length mm | 38,43 | 19,22 |
| TUBING, PVC-tube, average length mm | 23,09 | 11,54 |
| TUBING, SPECIAL TUBE/HOSE, average length mm | 7,06 | 7,06 |
| TUBING, ZIPPER-tube, average length mm | 12,72 | 6,36 |
| WIRES TO ASSEMBLY TABLE, average length mm | 1479,79 | 103,53 |
| **ASSEMBLY TOTAL:** | **4079,88** | **544,30** |
| Bundling harness after testing | 9,00 | 6,22 |
| CONNECTING to TEST TABLE | 251,00 | 22,09 |
| TESTING, electrical | 36,00 | 7,58 |
| **ELECTRICAL TEST OR VISUAL CHECKING TOTAL:** | **296,00** | **35,88** |
| HOUSING to assembly table | 55,00 | 3,03 |
| HOUSINGS to table | 173,00 | 9,52 |
| MODUL to table, avg length m | 9,00 | 1,20 |

| | | |
|---|---|---|
| **FINAL ASSEMBLY TOTAL:** | **237,00** | **13,74** |
| Bundling harness after testing | 1,00 | 0,41 |
| CONNECTING to TEST TABLE | 285,00 | 25,08 |
| Testing, clips and other passive components | 69,00 | 6,07 |
| TESTING, electrical for final product | 206,00 | 7,58 |
| **FINAL CHECKING TOTAL:** | **561,00** | **39,14** |
| PACKING; final packing | 9,00 | 4,88 |
| **FINAL PACKING TOTAL:** | **9,00** | **4,88** |
| PACKING | 9,00 | 4,88 |
| PACKING, to plastic bag | 13,00 | 4,29 |
| **PACKING TOTAL:** | **22,00** | **9,17** |
| | **5204,88** | **647,12** |

# Appendix 3: Ramp-up curve decision matrix

| | Circuits | Rating |
|---|---|---|
| | >30 | Low |
| **Circuit Count** | 30-100 | Medium Low |
| | 100-300 | Medium High |
| | <300 | High |

| | Rating |
|---|---|
| | High |
| **Diversity/Complexity (See below criteria)** | Medium |
| | Low |

**DIVERSITY/COMPLEXITY - Select Rating based on below guidelines.**

**High**

Harness with low repetition factor or Batch harness (High part number count)
Harness with multiple protection materials (tubes/Tapes/channels,shrinks)
Multiple long circuit lengths, difficult to handle (Longer than 8 meters)
High number of Retro Crimping after assembly.

**Medium**

Harness with medium repetition factor or Batch harnesses (Medium part number count)
Harness with multiple protection materials (tubes/Tapes)
Harness with mainly long circuit length, difficult to handle (Longer than 6 meters)
Some Retro Crimping after assembly on selected branches.

**Low.**

Harness with high repetition factor or Batch harness (Low part number count)
Harness with mainly tapes, spot tapes, cable channels, low tube content
Harnesses with mainly short circuit length (below 6 meters)
Little or no retro crimping, harness can be completed on assembly board.

| CARROUSEL RAMP UP CURVE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Harness Criteria | | Cycle Time / TAKT time (Mins)* | | | | | | |
| Circuit Count | Diversity/Complexity | >1 min | 1-2 mins | 2-3 mins | 3-4 mins | 4-6 mins | >6 mins | |
| High | High | 45 | 55 | 70 | 80 | 90 | 110 | Ramp up days |
| High | Medium | 35 | 45 | 55 | 70 | 80 | 90 | |
| High | Low | 30 | 35 | 45 | 55 | 70 | 80 | |
| Medium High | High | 25 | 30 | 35 | 45 | 50 | 55 | |
| Medium High | Medium | 20 | 25 | 30 | 40 | 45 | 50 | |
| Medium High | Low | 15 | 20 | 25 | 30 | 35 | 40 | |
| Medium Low | High | 20 | 25 | 30 | 35 | 45 | 55 | |
| Medium Low | Medium | 20 | 25 | 30 | 35 | 40 | 45 | |
| Medium Low | Low | 15 | 20 | 25 | 30 | 35 | 40 | |
| Low | High | 20 | 25 | 30 | 35 | 40 | 45 | |
| Low | Medium | 15 | 20 | 25 | 30 | 30 | 35 | |
| Low | Low | 15 | 15 | 20 | 25 | 25 | 30 | |

| Stationary / Single Work station RAMP UP CURVE | | | | |
|---|---|---|---|---|
| Harness Criteria | | Assy time (Mins)* | | |
| Circuit Count | Diversity/Complexity | >30 min | >30 mins | 30-60 mins |
| High | High | 70 | 110 | Ramp up days |
| High | Medium | 55 | 90 | |
| High | Low | 45 | 80 | |
| Medium High | High | 35 | 55 | |
| Medium High | Medium | 30 | 50 | |
| Medium High | Low | 25 | 40 | |
| Medium Low | High | 30 | 55 | |
| Medium Low | Medium | 30 | 45 | |
| Medium Low | Low | 25 | 40 | |
| Low | High | 30 | 45 | |
| Low | Medium | 25 | 35 | |
| Low | Low | 20 | 30 | |

*Consider time planned during ramp-up which is longer due to smaller output projections

| Work days | Work weeks | Week1 | Week2 | Week3 | Week4 | Week5 | Week6 | Week7 | Week8 | Week9 | Week10 | Week11 | Week12 | Week13 | Week14 | Week15 | Week16 | Week17 | Week18 | Week19 | Week20 | Week21 | Week22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **110 DAYS Curve** | **22** | 2% | 9% | 12% | 15% | 17% | 22% | 26% | 32% | 38% | 45% | 52% | 59% | 65% | 71% | 78% | 81% | 85% | 88% | 90% | 94% | 98% | 100% |
| **90 DAYS Curve** | **18** | 3% | 10% | 14% | 20% | 25% | 32% | 39% | 46% | 52% | 60% | 67% | 72% | 78% | 83% | 87% | 91% | 96% | 100% | | | | |
| **80 DAYS Curve** | **16** | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% | 91% | 96% | 100% | | | | | | |
| **70 DAYS Curve** | **14** | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% | | | | | | | | |
| **55 DAYS Curve** | **11** | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% | | | | | | | | | | |
| **45 DAYS Curve** | **9** | 7% | 15% | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% | | | | | | | | | | | | |
| **40 DAYS Curve** | **8** | 8% | 18% | 30% | 46% | 60% | 75% | 87% | 96% | 100% | | | | | | | | | | | | | |
| **35 DAYS Curve** | **7** | 10% | 22% | 36% | 54% | 71% | 87% | 96% | 100% | | | | | | | | | | | | | | |
| **30 DAYS Curve** | **6** | 12% | 25% | 39% | 57% | 78% | 95% | 100% | | | | | | | | | | | | | | | |
| **25 DAYS Curve** | **5** | 18% | 40% | 62% | 85% | 98% | 100% | | | | | | | | | | | | | | | | |

# Appendix 4: Initial ramp-up plan for SFTP products

**Output 1,0 = 90 pcs/crew**

**PP18 Engine - 2 x 14 station conveyor - 16 weeks ramp-up**

| 8hr crews per work day | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cw | 2225 | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 | 2240 |
| Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Output 1st crew - 70 day ramp-up | 5% | 9% | 13% | 17% | 23% | 27% | 33% | 39% | 45% | 51% | 59% | 67% | 75% | 83% | 91% | 100% |
| Output 2nd crew - 70 day ramp-up | 5% | 9% | 13% | 17% | 23% | 27% | 33% | 39% | 45% | 51% | 59% | 67% | 75% | 83% | 91% | 100% |
| Output 3rd crew - 55 day ramp-up | | 5% | 10% | 18% | 26% | 34% | 42% | 50% | 58% | 66% | 74% | 82% | 90% | 100% | 100% | 100% |
| Output 4th crew - 55 day ramp-up | | | 5% | 10% | 18% | 26% | 34% | 42% | 50% | 58% | 66% | 74% | 82% | 90% | 100% | 100% |
| Output 5th crew - 45 day ramp-up | | | | | 5% | 13% | 21% | 29% | 37% | 47% | 57% | 67% | 77% | 87% | 100% | 100% |
| Output 6th crew - 45 day ramp-up | | | | | 5% | 13% | 21% | 29% | 37% | 47% | 57% | 67% | 77% | 87% | 100% | 100% |
| Week production plan | 45 | 105 | 185 | 280 | 450 | 630 | 830 | 1025 | 1225 | 1440 | 1675 | 1910 | 2140 | 2385 | 2620 | 2700 |
| Day production plan | 9 | 21 | 37 | 56 | 90 | 126 | 166 | 205 | 245 | 288 | 335 | 382 | 428 | 477 | 524 | 540 |

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**Output 1,0 = 180 pcs/crew** 1crew = SA line + FA line

**PP18 Bumper 8 station conveyor - 14 week ramp-up**

| 8hr crews per work day | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cw | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 |
| Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Output 1st crew - 55 day ramp-up | 6% | 12% | 17% | 26% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% | 100% | 100% |
| Output 2nd crew - 55 day ramp-up | 6% | 12% | 17% | 26% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% | 100% | 100% |
| Output 3rd crew- 45 day ramp-up | | | | | | | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% |
| Week production plan | 110 | 215 | 310 | 470 | 685 | 945 | 1395 | 1750 | 2000 | 2225 | 2465 | 2585 | 2660 | 2700 |
| Day production plan | 22 | 43 | 62 | 94 | 137 | 189 | 279 | 350 | 400 | 445 | 493 | 517 | 532 | 540 |

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**Output 1,0 = 180 pcs/crew**

**PP18 Rearwall-conveyor 1x 6 station - 15 week ramp-up**

| 8hr crews per work day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cw | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 | 2240 |
| Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Output 1st crew - 45 day ramp-up | 6% | 15% | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% | 100% | 100% | 100% | 100% | 100% |
| Output 2nd crew - 45 day ramp-up | | | 6% | 15% | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% | 100% | 100% | 100% |
| Output 3rd crew - 35 day ramp-up | | | | | | | | 10% | 22% | 36% | 54% | 71% | 87% | 96% | 100% |
| Week production plan | 55 | 130 | 275 | 485 | 695 | 950 | 1175 | 1470 | 1760 | 2005 | 2245 | 2445 | 2580 | 2665 | 2700 |
| Day production plan | 11 | 26 | 55 | 97 | 139 | 190 | 235 | 294 | 352 | 401 | 449 | 489 | 516 | 533 | 540 |

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Wörth

Output 1,0 = 90 pcs/crew

**PP18 Roof - 2x18 station conveyor. 13week ramp-up**

| | 8hr crews per work day | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cw | 2237 | 2238 | 2239 | 2240 | 2241 | 2242 | 2243 | 2244 | 2245 | 2246 | 2247 | 2248 | 2249 |
| | Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| | Day customer order Wörth | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| | Day customer order TOT | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 |
| Line 1 | Output 1st crew - 55 day ramp-up | 6% | 12% | 17% | 26% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% | 100% |
| Line 1 | Output 2nd crew - 55day ramp-up | | 6% | 12% | 17% | 26% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% |
| Line 1 | Output 3rd crew - 55 day ramp-up | | 6% | 12% | 17% | 26% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% |
| Line 2 | Output 4th crew - 50 day ramp-up | | | 6% | 12% | 17% | 26% | 38% | 52% | 65% | 78% | 85% | 90% | 100% |
| Line 2 | Output 5th crew - 45 day ramp-up | | | | 6% | 15% | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% |
| Line 2 | Output 6th crew - 30 day ramp-up | | | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% |
| | Week production plan | 25 | 110 | 210 | 355 | 550 | 805 | 1165 | 1520 | 1850 | 2130 | 2380 | 2595 | 2700 |
| | Day production plan | 5 | 22 | 42 | 71 | 110 | 161 | 233 | 304 | 370 | 426 | 476 | 519 | 540 |

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Wörth

Output 1,0 = 90 pcs/crew

**PP18 Door - 2 x 12 station conveyor - 12 week ramp-up**

| | 8hr crews per work day | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cw | 2238 | 2239 | 2240 | 2241 | 2242 | 2243 | 2244 | 2245 | 2246 | 2247 | 2248 | 2249 |
| | Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| | Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| | Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Line 1 | Output 1st crew - 55 day ramp-up | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% |
| Line 1 | Output 2nd crew - 55 day ramp-up | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% |
| Line 1 | Output 3rd crew - 45 day ramp-up | | | 7% | 15% | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% |
| Line 2 | Output 4th crew - 45 day ramp-up | | | 7% | 15% | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% |
| Line 2 | Output 5th crew - 30 day ramp-up | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% | 100% |
| Line 2 | Output 6th crew - 30 day ramp-up | | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% |
| | Week production plan | 55 | 115 | 260 | 390 | 620 | 990 | 1345 | 1730 | 2080 | 2380 | 2620 | 2700 |
| | Day production plan | 11 | 23 | 52 | 78 | 124 | 198 | 269 | 346 | 416 | 476 | 524 | 540 |

Aksaray
CKD
Wörth

Output 1,0 = 180pcs/crew

**PP18 Frontwall - 1x 10 station conveyor- 11 week ramp-up**

| 8hr crews per work day | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cw | 2239 | 2240 | 2241 | 2242 | 2243 | 2244 | 2245 | 2246 | 2247 | 2248 | 2249 |
| Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Output 1st crew - 45 day ramp-up | 7% | 15% | 25% | 39% | 52% | 67% | 78% | 87% | 96% | 100% | 100% |
| Output 2nd crew - 35 day ramp-up | | | 10% | 22% | 36% | 54% | 71% | 87% | 96% | 100% | 100% |
| Output 3rd crew - 35 day ramp-up | | | | 10% | 22% | 36% | 54% | 71% | 87% | 96% | 100% |
| Week production plan | 65 | 130 | 310 | 640 | 990 | 1405 | 1830 | 2205 | 2505 | 2665 | 2700 |
| Day production plan | 13 | 26 | 62 | 128 | 198 | 281 | 366 | 441 | 501 | 533 | 540 |

Aksaray
CKD
Wörth

**Output 1,0 = 65 pcs/crew**

## PP18 Dashboard 1 x 24 station conveyor- 12 week ramp-up Aksaray

| | 8hr crews per work day | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Cw** | **2351** | **2352** | **2302** | **2303** | **2304** | **2305** | **2306** | **2307** | **2308** | **2309** | **2310** | **2311** |
| | **Week customer order Aksaray** | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | **Week customer order Wörth** | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | **Day customer order Aksaray** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** |
| | **Day customer order Wörth** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** |
| | **Day customer order TOT** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** |
| Line 1 | **Output 1st crew - 55 day ramp-up** | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% |
| Line 1 | **Output 2nd crew -55 day ramp-up** | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% |
| Line 1 | **Output 3rd crew -55 day ramp-up** | | | | | | | | | | | | |
| | **Week production plan** | **40** | **85** | **145** | **190** | **245** | **340** | **425** | **505** | **555** | **590** | **635** | **650** |
| | **Day production plan** | **8** | **17** | **29** | **38** | **49** | **68** | **85** | **101** | **111** | **118** | **127** | **130** |

Aksaray **1st line balance 65 per shift for Aksaray and CKD ramp-up**

**Output 1,0 =90 pcs/crew**

## PP18 Dashboard 2 x 24 station conveyor- 10 week ramp-up for CKD and 15 week ramp-up to full volume

| | 8hr crews per work day | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Cw** | **2339** | **2340** | **2341** | **2342** | **2343** | **2344** | **2345** | **2346** | **2347** | **2348** | **2349** | **2350** | **2351** | **2352** | **2402** | **2403** | **2404** | **2405** | **2406** | **2407** | **2408** | **2409** | **2410** | **2411** | **2412** | **2413** | **2414** |
| | **Week customer order Aksaray** | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | **Week customer order Wörth** | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | **Day customer order Aksaray** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** |
| | **Day customer order Wörth** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** |
| | **Day customer order TOT** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** |
| Line 1 | **Output 1st crew - 55 day ramp-up** | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 87% | 89% | 91% | 93% | 95% | 97% | 98% | 100% |
| Line 1 | **Output 2nd crew -55 day ramp-up** | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 87% | 89% | 91% | 93% | 95% | 97% | 98% | 100% |
| Line 1 | **Output 3rd crew -55 day ramp-up** | 11% | 19% | 25% | 32% | 45% | 55% | 66% | 77% | 82% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 85% | 87% | 89% | 91% | 93% | 95% | 97% | 98% | 100% |
| Line2 | **Output 4th crew - 55 day ramp-up** | | | | | | | | | | | | | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% | 100% | 100% | 100% |
| Line2 | **Output 5th crew -55 day ramp-up** | | | | | | | | | | | | | | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% | 100% | 100% |
| Line2 | **Output 6th crew -55 day ramp-up** | | | | | | | | | | | | | | | 6% | 13% | 22% | 29% | 38% | 52% | 65% | 78% | 85% | 90% | 98% | 100% | 100% |
| | **Week production plan** | **815** | **850** | **875** | **910** | **965** | **1015** | **1060** | **1110** | **1135** | **1150** | **1150** | **1150** | **1175** | **1235** | **1330** | **1435** | **1550** | **1685** | **1845** | **2050** | **2225** | **2365** | **2485** | **2580** | **2650** | **2675** | **2700** |
| | **Day production plan** | **163** | **170** | **175** | **182** | **193** | **203** | **212** | **222** | **227** | **230** | **230** | **230** | **235** | **247** | **266** | **287** | **310** | **337** | **369** | **410** | **445** | **473** | **497** | **516** | **530** | **535** | **540** |

Rebalance line 1 65->90 **2nd line start with 90 pcs line balance**
CKD
Wörth

Output 1,0 = see below per line

**PP18 Chassis - 24 week ramp-up Aksaray + 22 week ramp-up CKD + 28 week ramp-up Wörth**

| | 8hr crews per work day | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Cw** | **2247** | **2248** | **2249** | **2250** | **2251** | **2252** | **2302** | **2303** | **2304** | **2305** | **2306** | **2307** | **2308** | **2309** | **2310** | **2311** | **2312** | **2313** | **2314** | **2315** | **2316** | **2317** | **2318** | **2319** |
| | **Week customer order Aksaray** | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | **Week customer order Wörth** | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | **Day customer order Aksaray** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** |
| | **Day customer order Wörth** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** |
| | **Day customer order TOT** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** |
| Line 1 | **Output 1st crew - 110 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 2nd crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 3rd crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 2 | **Output 4th crew - 110 day ramp-up** | | 3% | 10% | 14% | 20% | 25% | 32% | 39% | 46% | 52% | 60% | 67% | 72% | 78% | 83% | 87% | 91% | 96% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 5th crew - 80 day ramp-up** | | | | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% | 91% | 96% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 6th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 3 | **Output 7th crew - 80 day ramp-up** | | | | | | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% | 91% | 96% | 100% | 100% | 100% | 100% |
| | **Output 8th crew - 70 day ramp-up** | | | | | | | | | | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% |
| | **Output 9th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 4 | **Output 10th crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 11th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 12th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 5 | **Output 13th crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 14th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 15th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 6 | **Output 13th crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 14th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 15th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Week production plan** | **0** | **5** | **20** | **30** | **50** | **75** | **115** | **145** | **185** | **220** | **265** | **315** | **360** | **405** | **455** | **500** | **540** | **580** | **615** | **635** | **655** | **665** | **675** | **680** |
| | **Day production plan** | **0** | **1** | **4** | **6** | **10** | **15** | **23** | **29** | **37** | **44** | **53** | **63** | **72** | **81** | **91** | **100** | **108** | **116** | **123** | **127** | **131** | **133** | **135** | **136** |

Output 1,0 = see below per line

**PP18 Chassis - 24 week ramp-up Aksaray + 22 week ramp-up CKD + 28 week ramp-up Wörth**

| | 8hr crews per work day | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Cw** | **2327** | **2328** | **2329** | **2330** | **2331** | **2332** | **2333** | **2334** | **2335** | **2336** | **2337** | **2338** | **2339** | **2340** | **2341** | **2342** | **2343** | **2344** | **2345** | **2346** | **2347** | **2348** | **2349** | **2350** | **2351** | **2352** |
| | **Week customer order Aksaray** | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | **Week customer order Wörth** | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | **Day customer order Aksaray** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** |
| | **Day customer order Wörth** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** |
| | **Day customer order TOT** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** |
| Line 1 | **Output 1st crew - 110 day ramp-up** | 10% | 14% | 20% | 25% | 32% | 39% | 46% | 52% | 60% | 67% | 72% | 78% | 83% | 87% | 91% | 96% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 2nd crew - 80 day ramp-up** | | | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% | 91% | 96% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 3rd crew - 80 day ramp-up** | | | | | | | | | | | 4% | 11% | 16% | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% |
| Line 2 | **Output 4th crew - 110 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 5th crew - 80 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 6th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% |
| Line 3 | **Output 7th crew - 80 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 8th crew - 70 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 9th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 4 | **Output 10th crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 11th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 12th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 5 | **Output 13th crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 14th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 15th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Line 6 | **Output 13th crew - 80 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 14th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Output 15th crew - 70 day ramp-up** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Week production plan** | **690** | **695** | **700** | **710** | **725** | **735** | **750** | **760** | **775** | **790** | **805** | **820** | **835** | **835** | **850** | **870** | **900** | **920** | **940** | **960** | **985** | **1005** | **1025** | **1050** | **1065** | **1085** |
| | **Day production plan** | **138** | **139** | **140** | **142** | **145** | **147** | **150** | **152** | **155** | **158** | **161** | **164** | **167** | **167** | **170** | **174** | **180** | **184** | **188** | **192** | **197** | **201** | **205** | **210** | **213** | **217** |

| | 8hr crews per work day | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Cw** | **2402** | **2403** | **2404** | **2405** | **2406** | **2407** | **2408** | **2409** | **2410** | **2411** | **2412** | **2413** | **2414** | **2415** | **2416** | **2417** | **2418** | **2419** | **2420** |
| | **Week customer order Aksaray** | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | **Week customer order Wörth** | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | **Day customer order Aksaray** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** | **120** |
| | **Day customer order Wörth** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** | **420** |
| | **Day customer order TOT** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** | **540** |
| Line 1 | **Output 1st crew - 110 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 2nd crew - 80 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 3rd crew - 80 day ramp-up** | 91% | 96% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Line 2 | **Output 4th crew - 110 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 5th crew - 80 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 6th crew - 70 day ramp-up** | 91% | 96% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Line 3 | **Output 7th crew - 80 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 8th crew - 70 day ramp-up** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Output 9th crew - 70 day ramp-up** | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% | 100% | 100% | 100% | 100% | 100% |
| Line 4 | **Output 10th crew - 80 day ramp-up** | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% | 91% | 96% | 100% | 100% | 100% | 100% |
| | **Output 11th crew - 70 day ramp-up** | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% | 100% | 100% | 100% | 100% |
| | **Output 12th crew - 70 day ramp-up** | | | | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% | 100% |
| Line 5 | **Output 13th crew - 80 day ramp-up** | | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% | 91% | 96% | 100% | 100% | 100% |
| | **Output 14th crew - 70 day ramp-up** | | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% | 100% | 100% | 100% |
| | **Output 15th crew - 70 day ramp-up** | | | | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% | 100% |
| Line 6 | **Output 13th crew - 80 day ramp-up** | | | 4% | 11% | 16% | 24% | 30% | 38% | 46% | 53% | 60% | 68% | 75% | 81% | 87% | 91% | 96% | 100% | 100% |
| | **Output 14th crew - 70 day ramp-up** | | | | | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% |
| | **Output 15th crew - 70 day ramp-up** | | | | | | 5% | 12% | 18% | 26% | 36% | 45% | 54% | 63% | 71% | 79% | 87% | 91% | 96% | 100% |
| | **Week production plan** | **1115** | **1165** | **1230** | **1300** | **1385** | **1500** | **1620** | **1745** | **1880** | **2015** | **2145** | **2260** | **2375** | **2470** | **2555** | **2615** | **2660** | **2690** | **2700** |
| | **Day production plan** | **223** | **233** | **246** | **260** | **277** | **300** | **324** | **349** | **376** | **403** | **429** | **452** | **475** | **494** | **511** | **523** | **532** | **538** | **540** |

| | | Shift | | Day | % |
|---|---|---|---|---|---|
| Line 1 | 4 x stationary - RL Standard + GGVS | 18 | | 54 | 10% |
| Line 2 | 4 station conveyor - LL Standard + GGVS | 34 | | 102 | 19% |
| Line 3 | 4 station conveyor - LL Standard + GGVS | 34 | | 102 | 19% |
| Line 4 | 4 station conveyor - LL Standard + GGVS | 34 | | 102 | 19% |
| Line 5 | 4 station conveyor - LL Standard + GGVS | 34 | | 102 | 19% |
| Line 6 | 4 station conveyor - LL Standard + GGVS | 26 | | 78 | 14% |
| | | 180 | 540 | 540 | 100% |

Aksaray
CKD
Wörth

# Appendix 5: Weekly direct labour plan

| | jaan.22 | | | | veebr.22 | | | | märts.22 | | | | | apr.22 | | | | mai.22 | | | | juuni.22 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wk01 | Wk02 | Wk03 | Wk04 | Wk05 | Wk06 | Wk07 | Wk08 | Wk09 | Wk10 | Wk11 | Wk12 | Wk13 | Wk14 | Wk15 | Wk16 | Wk17 | Wk18 | Wk19 | Wk20 | Wk21 | Wk22 | Wk23 | Wk24 | Wk25 | Wk26 |
| Engine | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 48 | 48 | 48 | 48 | 48 | 72 | 72 | 96 | 96 |
| Bumper | 0 | 0 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 35 | 35 | 35 | 35 | 53 | 53 | 53 | 53 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| Rear wall | 0 | 0 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 24 | 24 | 24 | 24 | 24 | 24 | 36 | 36 | 36 | 36 | 36 | 36 | 48 | 48 | 48 |
| Doors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Roof | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 44 |
| Frontwall | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 |
| IP | 0 | 0 | 0 | 0 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| Chassis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 16 | 16 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| Total DL Heads | 24 | 24 | 54 | 54 | 68 | 68 | 68 | 68 | 112 | 128 | 143 | 173 | 173 | 175 | 175 | 193 | 214 | 288 | 288 | 306 | 306 | 306 | 330 | 342 | 365 | 380 |

| | juuli.22 | | | | aug.22 | | | | | sept.22 | | | | okt.22 | | | | nov.22 | | | | | dets.22 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wk27 | Wk28 | Wk29 | Wk30 | Wk31 | Wk32 | Wk33 | Wk34 | Wk35 | Wk36 | Wk37 | Wk38 | Wk39 | Wk40 | Wk41 | Wk42 | Wk43 | Wk44 | Wk45 | Wk46 | Wk47 | Wk48 | Wk49 | Wk50 | Wk51 | Wk52 |
| Engine | 120 | 120 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 120 | 120 | 120 | 120 | 120 | 120 | 96 | 96 | 96 | 96 |
| Bumper | 71 | 71 | 88 | 88 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 106 | 88 | 88 | 88 | 88 | 88 |
| Rear wall | 48 | 60 | 59,85 | 66 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 60 | 60 | 60 | 60 | 60 |
| Doors | 48 | 48 | 48 | 48 | 48 | 48 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 |
| Roof | 44 | 44 | 44 | 59,28 | 59 | 59 | 59,28 | 59 | 89 | 89 | 89 | 119 | 148 | 148 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 |
| Frontwall | 41 | 41 | 41 | 41 | 41 | 41 | 82 | 82 | 82 | 82 | 103 | 103 | 103 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 |
| IP | 14 | 14 | 14 | 14 | 14 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| Chassis | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 66 | 66 | 66 | 66 | 66 | 66 | 66 | 66 | 66 |
| Total DL Heads | 419 | 431 | 472 | 493 | 517 | 526 | 615 | 615 | 661 | 661 | 682 | 711 | 741 | 809 | 839 | 863 | 839 | 855 | 855 | 855 | 855 | 826 | 802 | 802 | 802 | 802 |

| | jaan.23 | | | | veebr.23 | | | | märts.23 | | | | | apr.23 | | | | mai.23 | | | | | juuni.23 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wk01 | Wk02 | Wk03 | Wk04 | Wk05 | Wk06 | Wk07 | Wk08 | Wk09 | Wk10 | Wk11 | Wk12 | Wk13 | Wk14 | Wk15 | Wk16 | Wk17 | Wk18 | Wk19 | Wk20 | Wk21 | Wk22 | Wk23 | Wk24 | Wk25 | Wk26 |
| Engine | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Bumper | 88 | 88 | 88 | 88 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| Rear wall | 60 | 60 | 60 | 60 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Doors | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Roof | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 119 | 119 | 119 | 119 |
| Frontwall | 123 | 123 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 |
| IP | 94 | 94 | 94 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 |
| Chassis | 132 | 132 | 132 | 198 | 198 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 264 |
| Total DL Heads | 915 | 915 | 894 | 1054 | 1024 | 1090 | 1090 | 1090 | 1066 | 1066 | 1066 | 1066 | 1066 | 1016 | 1016 | 1016 | 1016 | 992 | 992 | 992 | 992 | 992 | 963 | 963 | 963 | 963 |

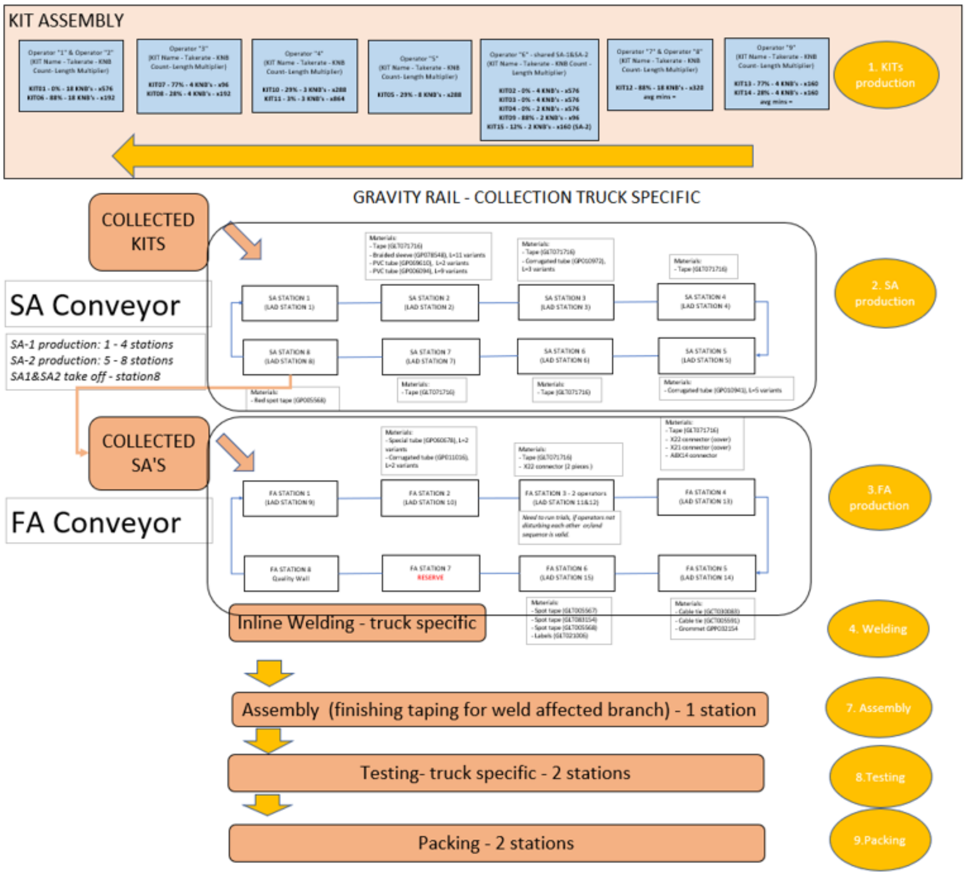
| | juuli.23 | | | | aug.23 | | | | | sept.23 | | | | okt.23 | | | | nov.23 | | | | | dets.23 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wk27 | Wk28 | Wk29 | Wk30 | Wk31 | Wk32 | Wk33 | Wk34 | Wk35 | Wk36 | Wk37 | Wk38 | Wk39 | Wk40 | Wk41 | Wk42 | Wk43 | Wk44 | Wk45 | Wk46 | Wk47 | Wk48 | Wk49 | Wk50 | Wk51 | Wk52 |
| Engine | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Bumper | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| Rear wall | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Doors | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Roof | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 |
| Frontwall | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 |
| IP | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 282 | 282 | 282 | 376 | 376 | 376 | 470 | 470 |
| Chassis | 264 | 264 | 264 | 264 | 264 | 330 | 330 | 330 | 330 | 330 | 396 | 396 | 396 | 396 | 396 | 396 | 396 | 396 | 396 | 396 | 396 | 396 | 396 | 462 | 462 | 528 |
| Total DL Heads | 963 | 963 | 963 | 963 | 963 | 1029 | 1029 | 1029 | 1029 | 1029 | 1095 | 1095 | 1095 | 1095 | 1095 | 1095 | 1095 | 1095 | 1189 | 1189 | 1189 | 1283 | 1283 | 1349 | 1443 | 1509 |

| | jaan.24 | | | | veebr.24 | | | | märts.24 | | | | | apr.24 | | | | mai.24 | | | | | juuni.24 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wk01 | Wk02 | Wk03 | Wk04 | Wk05 | Wk06 | Wk07 | Wk08 | Wk09 | Wk10 | Wk11 | Wk12 | Wk13 | Wk14 | Wk15 | Wk16 | Wk17 | Wk18 | Wk19 | Wk20 | Wk21 | Wk22 | Wk23 | Wk24 | Wk25 | Wk26 |
| Engine | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Bumper | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| Rear wall | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Doors | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Roof | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 |
| Frontwall | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 |
| IP | 470 | 470 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 |
| Chassis | 528 | 594 | 594 | 660 | 660 | 726 | 726 | 792 | 792 | 924 | 924 | 990 | 990 | 990 | 990 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 |
| Total DL Heads | 1509 | 1575 | 1669 | 1735 | 1735 | 1801 | 1801 | 1867 | 1867 | 1999 | 1999 | 2065 | 2065 | 2065 | 2065 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 |

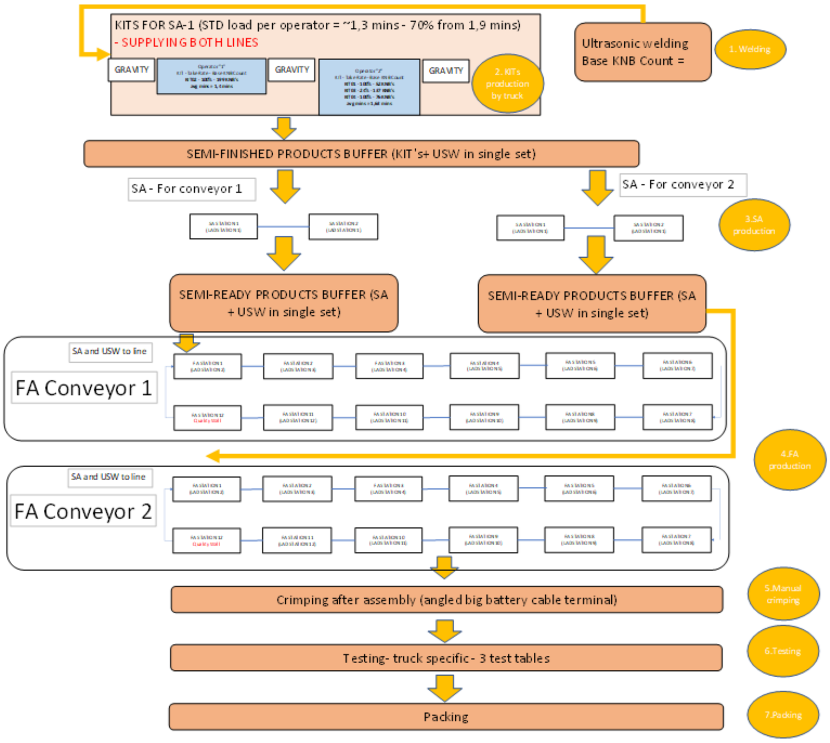
| | juuli.24 | | | | aug.24 | | | | | sept.24 | | | | okt.24 | | | | nov.24 | | | | | dets.24 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wk27 | Wk28 | Wk29 | Wk30 | Wk31 | Wk32 | Wk33 | Wk34 | Wk35 | Wk36 | Wk37 | Wk38 | Wk39 | Wk40 | Wk41 | Wk42 | Wk43 | Wk44 | Wk45 | Wk46 | Wk47 | Wk48 | Wk49 | Wk50 | Wk51 | Wk52 |
| Engine | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Bumper | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| Rear wall | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Doors | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Roof | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 |
| Frontwall | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 82 |
| IP | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 564 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 |
| Chassis | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 990 | 990 | 990 | 990 | 990 | 990 | 990 | 990 | 990 | 990 | 990 | 990 | 990 |
| Total DL Heads | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2131 | 2037 | 2037 | 2037 | 2037 | 2037 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 | 1971 |

# Appendix 6: Individual process flowcharts

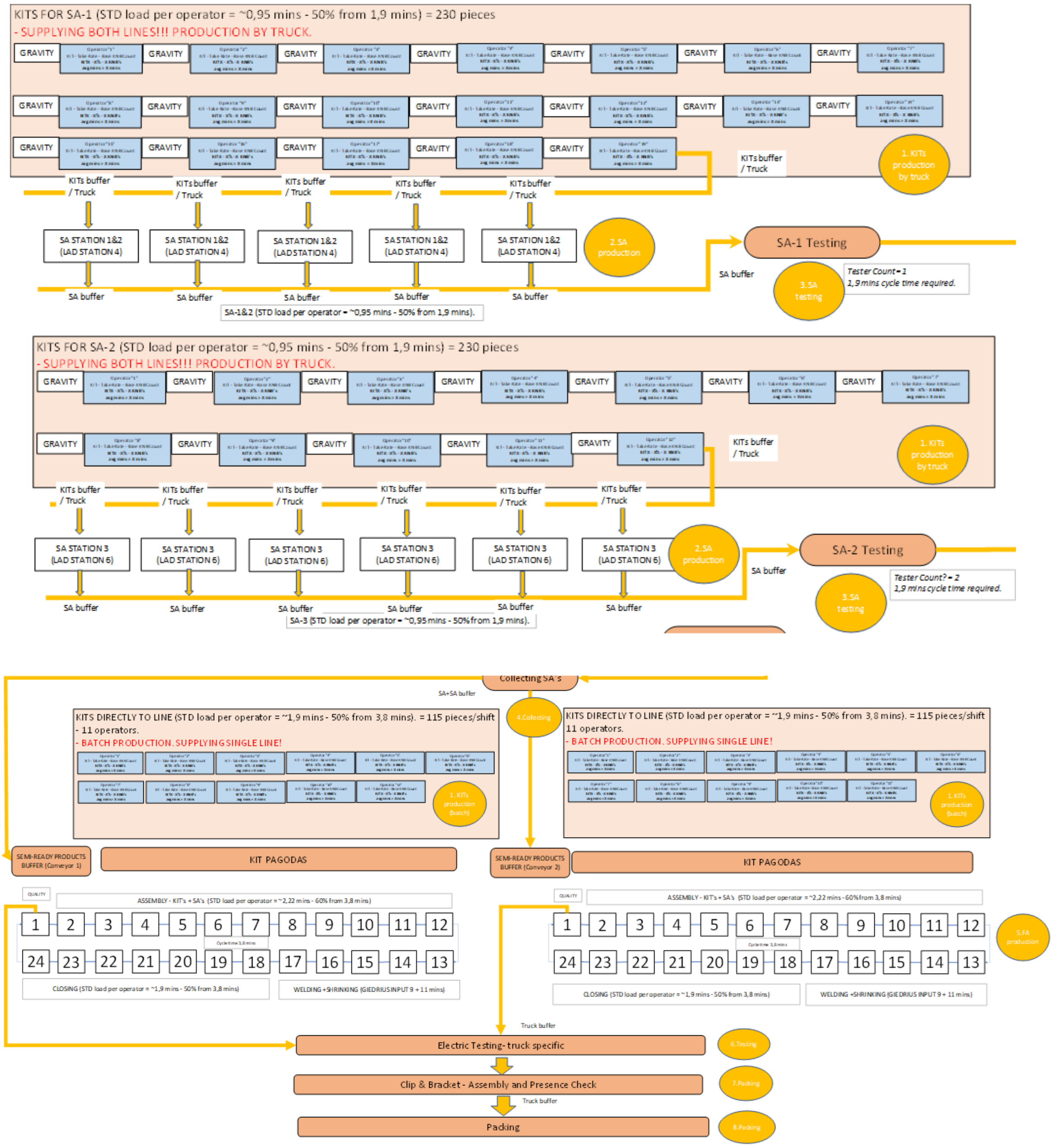
## XVK82 Bumper



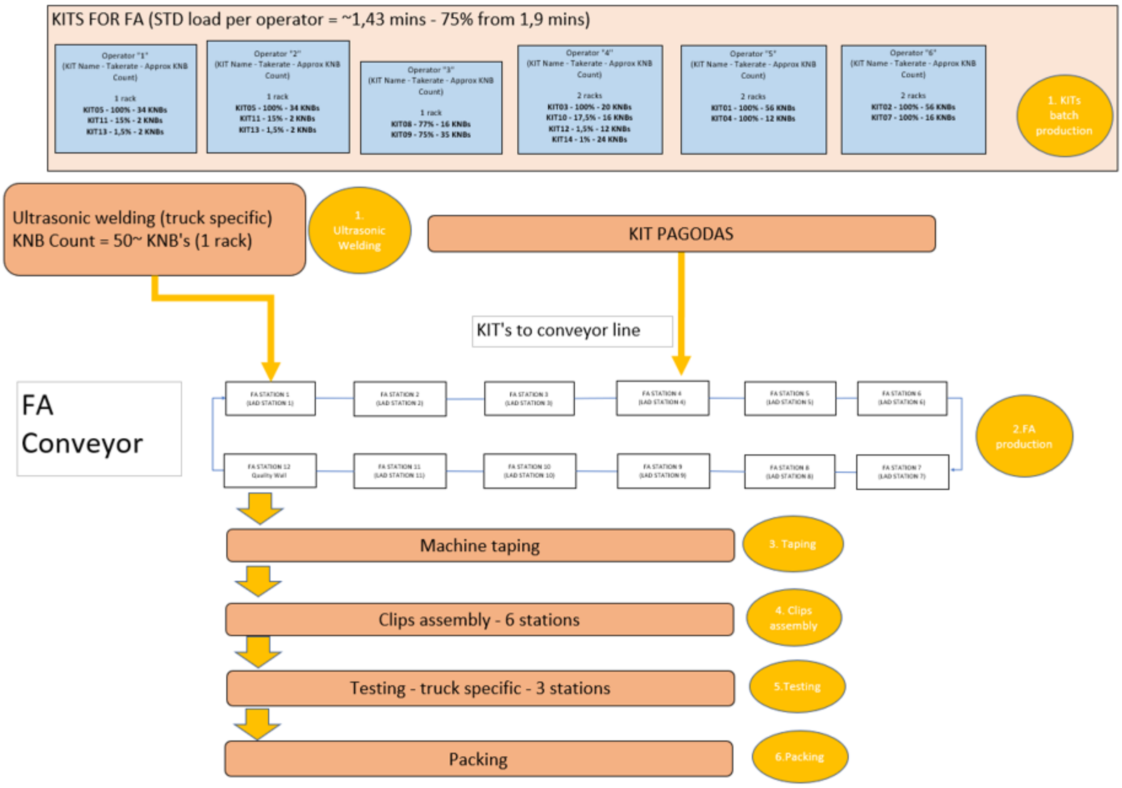

## XVK83 Engine



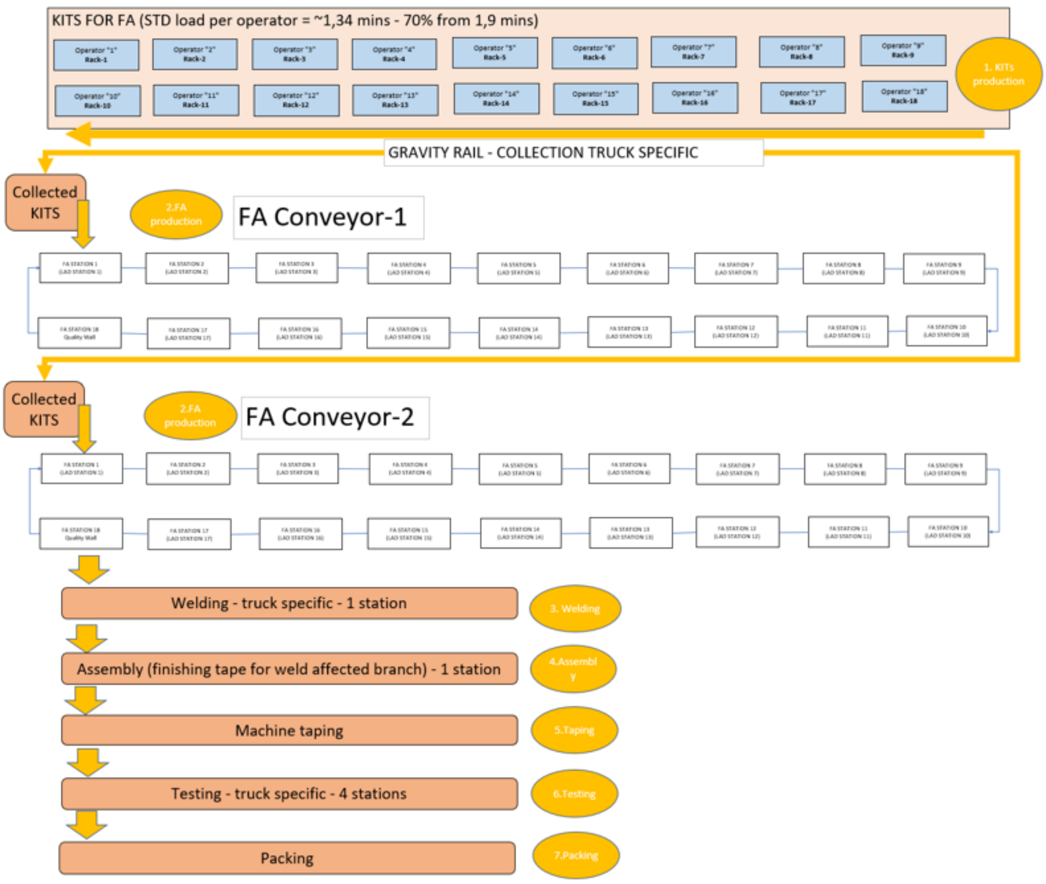
# XVK84 dashboard harness



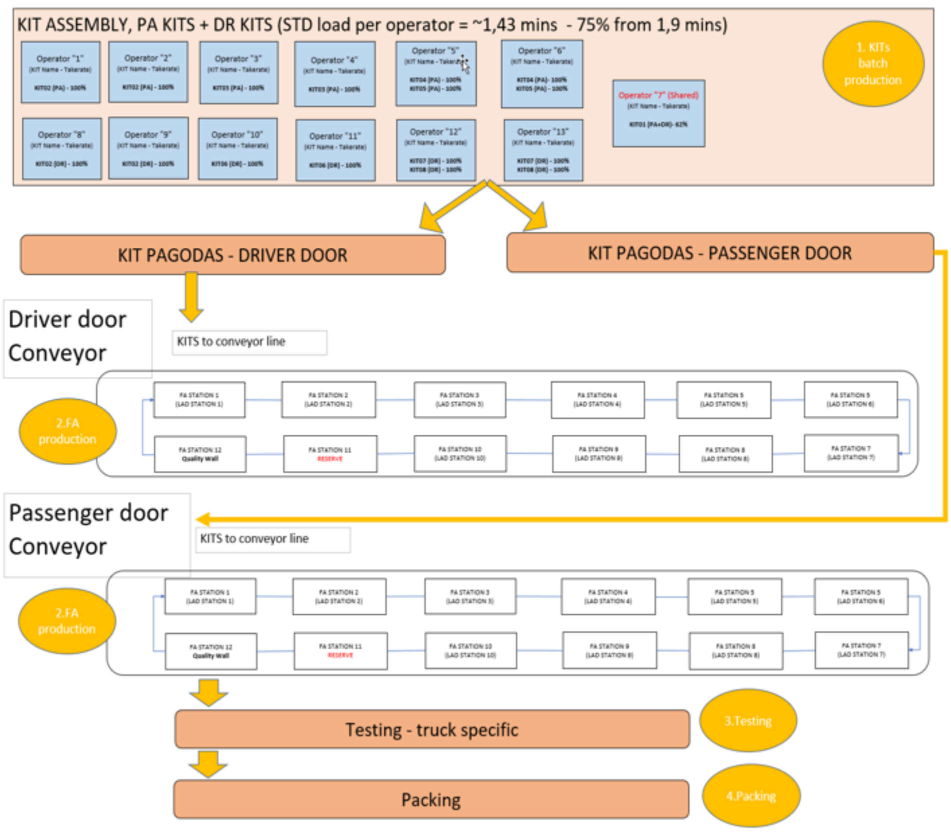
# XVK85 Front Wall



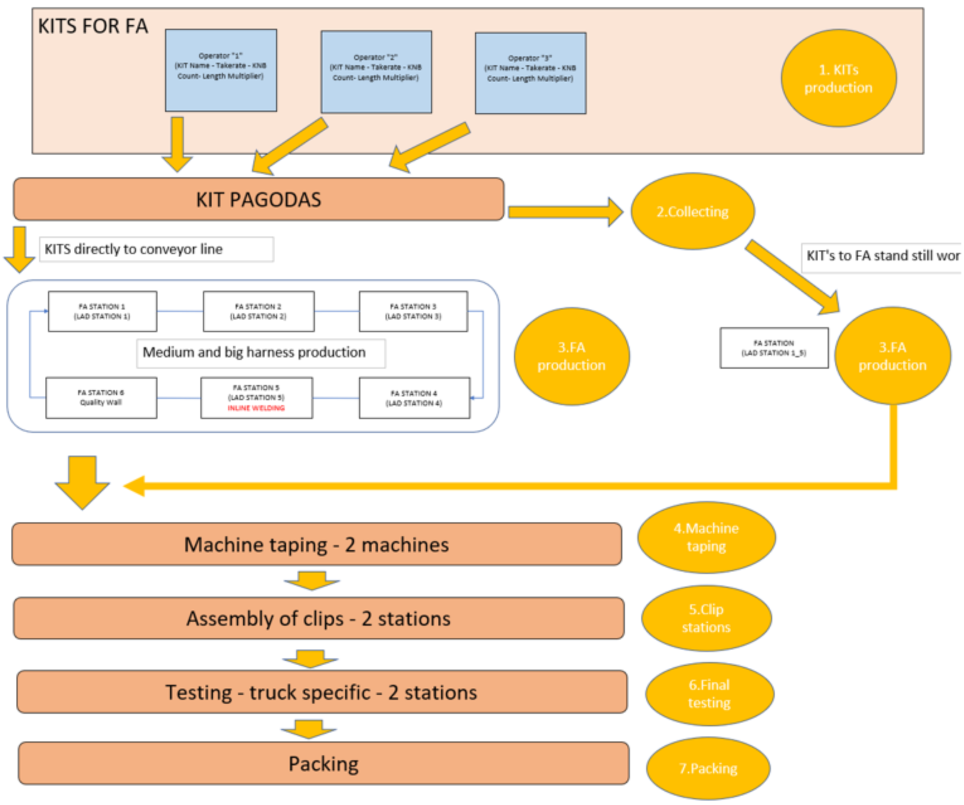

# XVK86 Roof harness

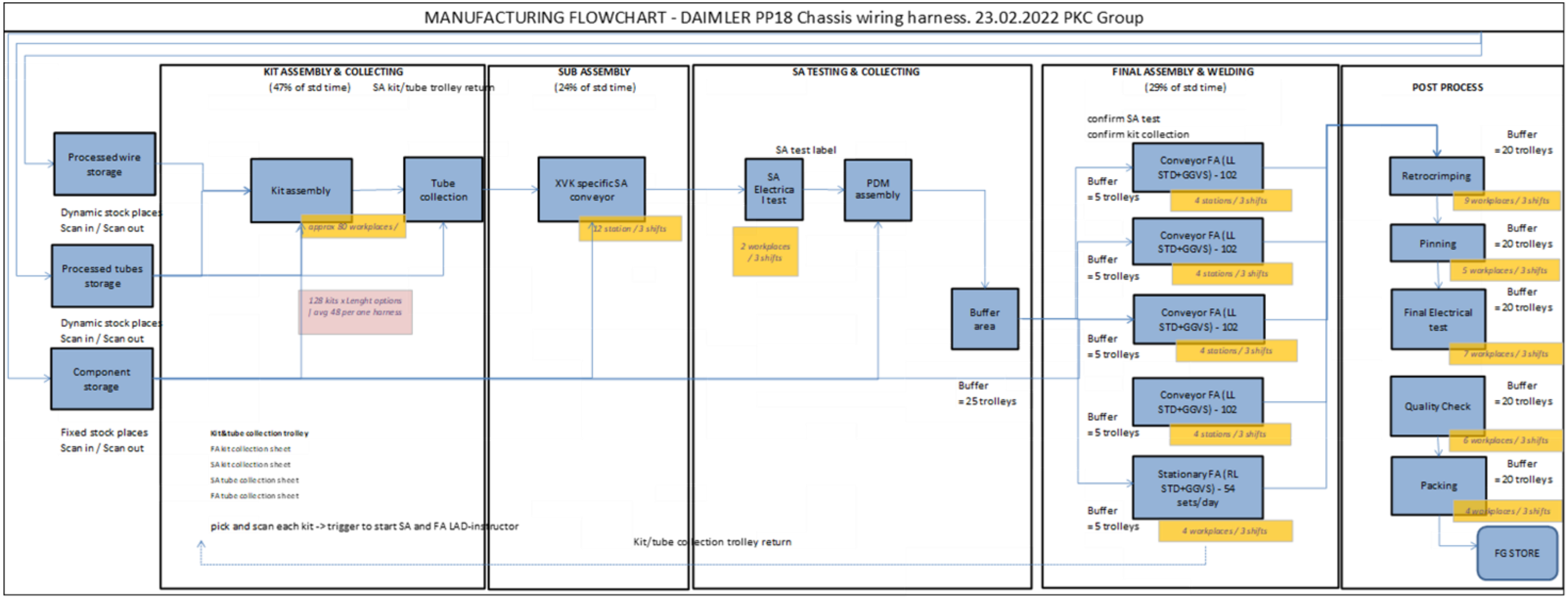


# XVK87&XVK88 Door harness

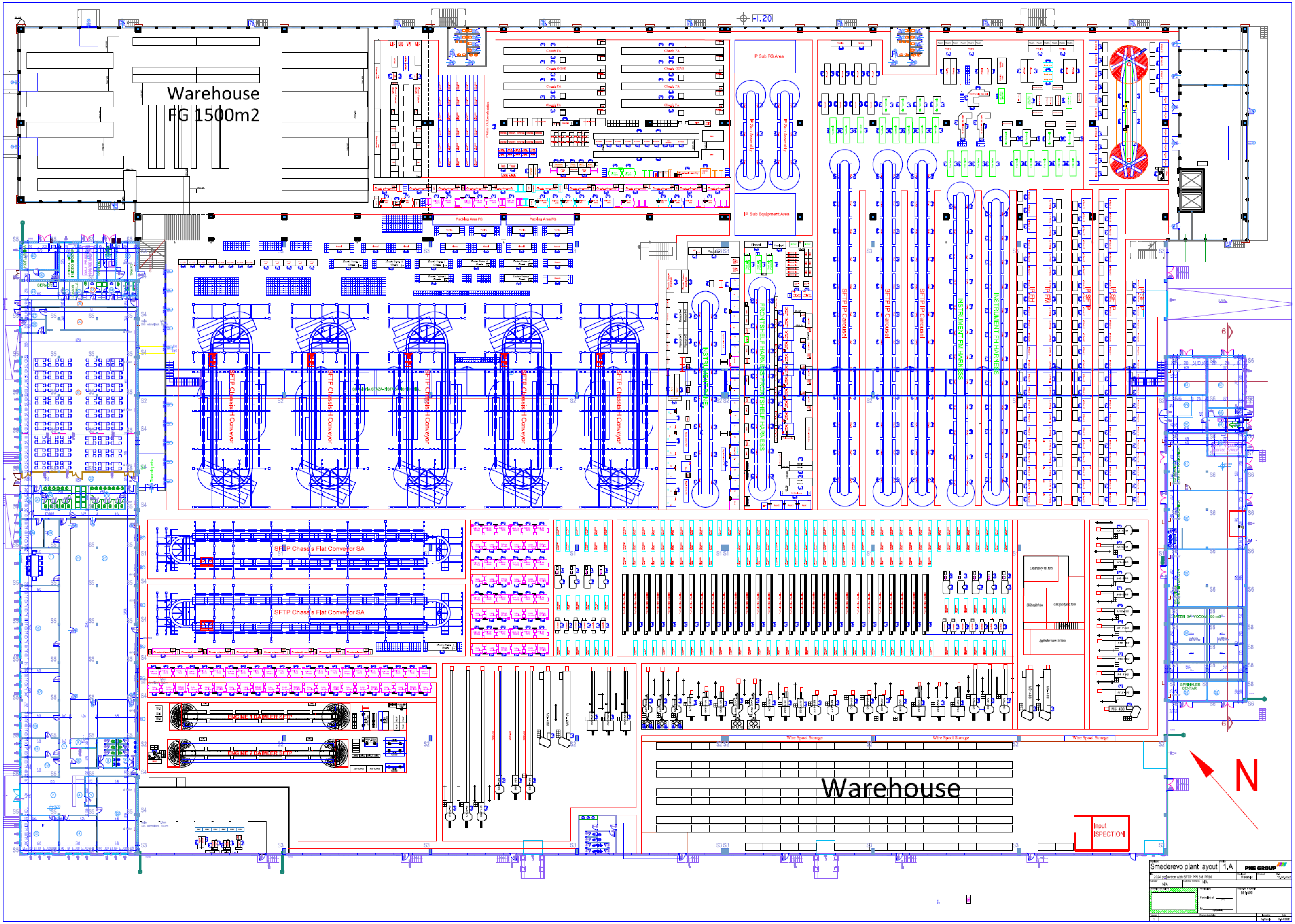



# XVK89 Rear Wall harness

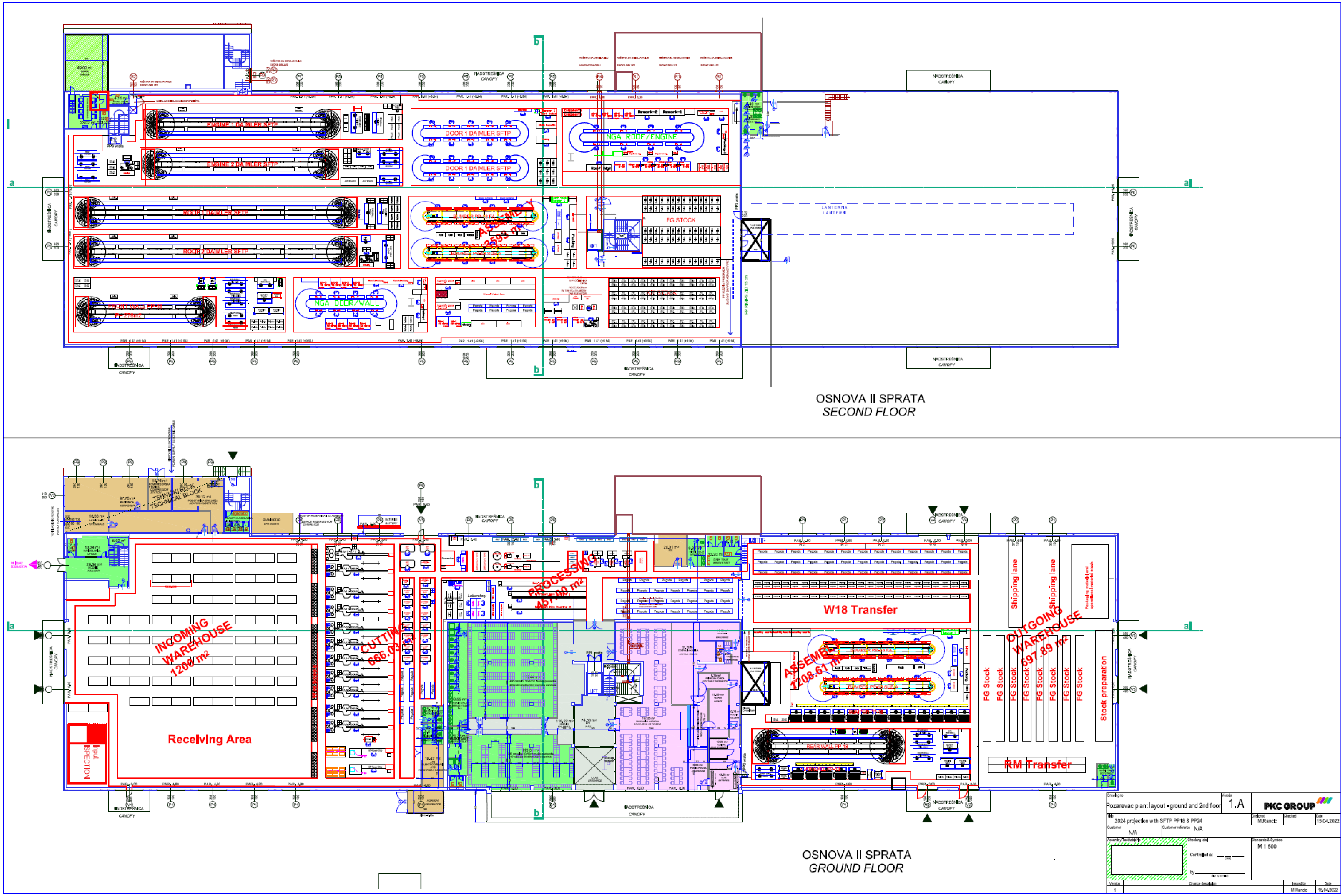



MANUFACTURING FLOWCHART - DAIMLER PP18 Chassis wiring harness. 23.02.2022 PKC Group
KIT ASSEMBLY & COLLECTING
(47% of std time)
SA kit/tube trolley return
SUB ASSEMBLY
(24% of std time)
SA TESTING & COLLECTING
FINAL ASSEMBLY & WELDING
(29% of std time)
POST PROCESS
Processed wire storage
Dynamic stock places
Scan in / Scan out
Processed tubes storage
Dynamic stock places
Scan in / Scan out
Component storage
Fixed stock places
Scan in / Scan out
Kit assembly
approx 80 workplaces /
Tube collection
128 kits x Lenght options / avg 48 per one harness
Kit&tube collection trolley
FA kit collection sheet
SA kit collection sheet
SA tube collection sheet
FA tube collection sheet
pick and scan each kit -> trigger to start SA and FA LAD-instructor
XVK specific SA conveyor
12 station / 3 shifts
Kit/tube collection trolley return
SA test label
SA Electrical test
2 workplaces / 3 shifts
PDM assembly
Buffer area
Buffer = 25 trolleys
confirm SA test
confirm kit collection
Conveyor FA (LL STD+GGVS) - 102
Conveyor FA (LL STD+GGVS) - 102
Conveyor FA (LL STD+GGVS) - 102
Conveyor FA (LL STD+GGVS) - 102
Stationary FA (RL STD+GGVS) - 54 sets/day
Buffer = 5 trolleys
4 stations / 3 shifts
4 workplaces / 3 shifts
Retrocrimping
9 workplaces / 3 shifts
Pinning
5 workplaces / 3 shifts
Final Electrical test
7 workplaces / 3 shifts
Quality Check
6 workplaces / 3 shifts
Packing
4 workplaces / 3 shifts
Buffer = 20 trolleys
FG STORE

## Appendix 7: Smederevo plant layout



## Appendix 8: Pozarevac plant layout (ground and 2nd floor)



# Appendix 9: Process readiness review check sheet

| PKC GROUP | PROCESS READINESS REVIEW | | | | |
|---|---|---|---|---|---|
| **A. HR** | | | | | |
| QUESTION: | EVIDENCE REQUIRED | *LOOK FOR* | Score | G/Y/R | OBSERVATIONS |
| 1 Are Training plans defined for operators, quality control, packing… Is there a documented information on which the training plan is based on? | Recorded evidence of training plans | *Documented training plans, attendance lists* | | R | |
| 2 Have trainings been conducted, are personnel trained? | Recorded evidence of training participation | *Attendance lists* | | R | |
| 3 Is operator qualification displayed? | Qualification matrix | *Documented qualification matrix* | | R | |
| 4 Are there Instructers / Trainers assigned | Check with HR for resources | *Are they focusing on the right areas where support is needed* | | R | |
| **B. Engineering** | | | | | |
| QUESTION: | EVIDENCE REQUIRED | *LOOK FOR* | Score | G/Y/R | OBSERVATIONS |
| 1 Is there sufficient capacity to cover the Customer demand on all processes. | Line Balance with Customer Takt, tester capacity, process area capacity (welding, crimping etc) | *Each process to have capacity calculation* | | R | |
| 2 Is one piece flow assured, for carrousel type production, no imbalance between processes | Check cycle times to assure no imbalance exists, refer to capacity information | *Any build of parts between processes, for example between line and tester* | | R | |
| 3 Is the total cycle time identified at each operation? | Cycle time at each operation | *Each operation to have the cycle time posted.* | | R | |
| 4 Are all materials clearly identified and labelled | Posting of part numbers used at each operation. | *Correct part numbers being used at each operation* | | R | |
| 5 Have the required production tools & eqiupment been defined? | A listing of all required tools for each operation | *Each operation to have a visualization with tool required* | | R | |
| 6 Is the technical documentation, work & engineering instructions and LAD instructions defined, approved and distributed? | Procedures and work instructions, technical drawings, engineering instructions, LAD instructions | *Approved technical documentation, distribution lists, check version numbers* | | R | |
| 7 Is the layout suitable for production? | Space, work conditions (temperature, humidity…) | *Area should be sized appropriately* | | R | |
| 8 Are all areas clearly marked, floor markings | According to Layout | *Check if all markings are available, or if more need to be added* | | R | |
| 9 Are work stations marked according to the process flow chart? | Marking on stations, process flow | *Marked work stations according to PFC, PFC is displayed on the production area* | | R | |
| 10 Are boxes with appropriately material marked? | Marked material boxes | *Marking is visible and matches the material inside* | | R | |
| 11 Are there soft mats available for standing posiitions | Pinning worktations, carrouels lines, testers, inspection areas | *Check if sufficient mats are in use* | | R | |
| 12 Is there good and bad samples available for to verify the CPs on the Test table? | Check samples | *Tacking document at the workstation* | | R | |
| 13 Ergonomics of workplaces | Low or high assembly points on the assembly boards, extremes to be avoided | Look for issues on the assembly boards in particular and the posture of the operators | | R | |
| 14 Material storage betweem processes | Are there defined storage places and storage methods between processes | Look for method how harnesses are stored in between processes. | | R | |
| 15 Sharp edges, pinch points on equipment, risk to damage wire or components | Visual check for these kind of risks, observe the process | *Sharp edges, pinch points that can be a risk to product quality* | | R | |
| 16 Is there sufficient lighting on all areas to support good quality assembly | Overall lighting and specific workstation lighting on assembly boards, and quality inspection stations, plus other difficult assembly areas | *Check for local lighting in appropriate areas, assembly boards, pinning areas, quality inspection areas.* | | R | |
| 17 Seperation of similar looking components on stoarge places and at workstations due to risk of mixing | Check for correct separation of simlar components which could be mixed in the process of assembly | *Same connectors which might have only marking difference, or coding differences* | | R | |
| **C. Maintenance** | | | | | |
| QUESTION: | EVIDENCE REQUIRED | *LOOK FOR* | Score | G/Y/R | OBSERVATIONS |
| 1 Have the maintenance plans been developed for machines and tools? | Maintenance plans | *Regularly recorded actions according to maintenance plans* | | R | |
| 2 Are maintenance objectives defined and recorded? | Maintenance plan for each equipment. Checklist of what needs tro be performed during checks | *Check records, and compare them to the evidence in the shop floor* | | R | |
| 3 Is there a sufficient amount of replacement parts? | Replacement part storage and recorded amounts of parts | *Inventory lists* | | R | |
| 4 Is automomous maintenance carried out according to plan | Check if maintenance cards are available and with right level of detail | *Check records to ensure checks are being done, Interview operator to check if trhey understand the process and what they need to do/* | | R | |
| 5 Is there equipment which must be identified as Critical / Unique with no backup | Check critical equipment list for the Plant | *Ensure that reaction plan is available in case of critical equipment* | | R | |
| 6 Check interlocks are functional on equipment | Check if interlock is functional, simulate with locks open to ensure working correctly | *Check that there are no dummy interlock bypasses available to non maintenance personnel.* | | R | |
| 7 is the general coindition of the equipment to a satisfactory level | Check if equipment is clean, with safety guards, well maintained visually | *Visual check, also check records of maintenance activities in Arrow* | | R | |

## E. Quality

| | QUESTION: | EVIDENCE REQUIRED | LOOK FOR | Score | G/Y/R | |
|---|---|---|---|---|---|---|
| 1 | Are the product special characteristics defined? | Special characteristics are highlighted | *Noted in procedures, work instructions, CP, work stations…* | | R | |
| 2 | Are boundry samples present for each produced part? | Master samples | *Condition of master samples, are master samples approved* | | R | |
| 3 | Are Product Measurement Systems calibrated and work instructions to utilize the gage present? | Calibration Sticker on the gage not old and work instructions | *Gage tag and how the operator follows gaging instructions* | | R | |
| 4 | Is production validated? | Validation evidence | *First piece approval records* | | R | |
| 5 | Verify a part is within specification | Part measured with production gages | *Dimensional discrepancies* | | R | |
| 6 | Are objectives displayed? | Posted record on the shop floor | *PPM charts, Qalerts, records regularly updated* | | R | |
| 7 | Is the control plan displayed in the production area? | Control plan | *Valid revision* | | R | |
| 8 | Is there any error proofing present? | Error detection is present | *Signals to operators that an error has been made* | | R | |
| 9 | Is error proofing equipment validated? | Electrical tester validation | *Check records for validation of testing programs and secondary functions on the electrical testers (recognition of seals, tapes, cable ties…)* | | R | |
| 10 | Verify the parts are within specification | Measurement reports | *Product Audit results* | | R | |
| 11 | Check that operators are not using their own tools, or inappropriate tools | Interview operators | *Remove all inappropriate tools and issue correct equipment if needed* | | R | |
| 12 | Is quality feedback from quality wall and electrical test established and working effectively | Is there a feedbakc process or communication loop from Tester to assembly, or from Quality wall to assembly? | Check how the feedbakc is working in practice, is it effective? | | R | |

## F. Production

| | QUESTION: | EVIDENCE REQUIRED | LOOK FOR | Score | G/Y/R | |
|---|---|---|---|---|---|---|
| 1 | Are objectives displayed? | Posted record on the shop floor | *Production plan vs Actual production* | | R | |
| 2 | Is the production taking place according to the process flow chart? | Compare the PFC with the state in the shop floor | *Bottle necks, material in between operations…* | | R | |
| 3 | Is the production taking place according to the control plan? | Compare the CP with the state in the shop floor | *Are control points noted in the CP respected, do the operators adheret to the CP, are tools noted in use, are the WI's note available at the work stations* | | R | |
| 4 | Are drawing, tools, racks proper condition? | Without mechanical damages, scratches, potentional risk of product quality | *Check the condition* | | R | |
| 5 | Are machine checked before the start of production? | Reorded evidence | *Check records* | | R | |
| 6 | Is all equipment in use controlled? | | *Uncontrolled equipment* | | R | |
| 7 | Is the rework process in place? | Identification of nonconforming and reworked products, rework documentation (procedure, instructions, records), operator qualification, rework tool validation and peridocal check | *Check records, product flow, operator and tool qualfication* | | R | |
| 8 | Are personnel trained for rework and do they have the tools and equipment | Checlk operators training records. | *Check tools and equipment for rework activities* | | | |
| 9 | Are there data collection forms available to allow Quality / production information to be collected? | Ensure forms are available at required workstations to collect data | *FTQ forms at tester, rework labels, production documents* | | R | |

## G. Supply chain

| | QUESTION: | EVIDENCE REQUIRED | LOOK FOR | Score | G/Y/R | |
|---|---|---|---|---|---|---|
| 1 | Are condition suitable for material storage in the production area? | Proper storage conditions | *Materials stored in proper boxes, conditions are according to material data sheets* | | R | |
| 2 | Is First In/First Out maintained at each operation? | Part box dates at each operation show oldest material being used first | *Look for stock dates at each storage location for each operation* | | R | |
| 3 | Are Min/Max quantities displayed at each operation's part storage location? | Min/Max inventory label at each operation's storage location | *Overstocking or understocking of material based upon min/max requirements* | | R | |
| 4 | Are the packaging instructions defined and available at the packaging area? | Instructions for packaging of finished goods | *Is the product packaged according to the instructions, check package suitability* | | R | |
| 5 | Is the storage area for the packaged product suitable? | | *Check conditions (temperature, humidity), boxes without damage, box identification* | | R | |

## H. EHS

| | QUESTION: | EVIDENCE REQUIRED | LOOK FOR | Score | G/Y/R | |
|---|---|---|---|---|---|---|
| 1 | Are environmental and safety instructions and warinings available in the production area? | EHS instructions | *Are documents up to date?* | | R | |
| 2 | Are safety concerns noted in the work instructions for machine and tool usage? | | *Review instructions* | | R | |
| 3 | Do operators have safety equipment? | Safety shoes, glasses, gloves… | *Check sample of operators* | | R | |
| 4 | Is the risk assessed for all work places? | Risk assessment | *Check risk assessment documentation* | | R | |
| 5 | Are patrhways and emergency ways free from obstruction | Area according to planned layout | *Visual check of the areas to ensure all walkways are clear* | | R | |
| 6 | Are the liquids/chemicals on original bottles and identified with the labels .<br>Are datasheets available within work stations ? | Check chemicals and ensure they are labelled | Check chemicals and ensure they are labelled<br>Request the MSDS sheets | | R | |
| 7 | Is waste properly disposed? | Dedicated marked places for disposition of all kinds of waste (hazardous waste, copper, paper, plastic…) | *Check bins to ensure correct segregation of waste* | | R | |

## I. 6S

| | QUESTION: | EVIDENCE REQUIRED | *LOOK FOR* | Score | G/Y/R | |
|---|---|---|---|---|---|---|
| 1 | Are only things that are part of the process existing in the work area (Sort)? | No excess equipment/tools or parts present in work area | *Things not being used to produce in the work area* | | R | |
| 2 | Are things set in order with visual controls present(Set in Order)? | Floor markings and signs identifying everything in the work area | *Materials in the work area without designation of what it is or where it belongs.* | | R | |
| 3 | Is the area clean(Shine)? | Only debris from the past 8 hours of production appears present in the work area | *Leaking equipment, debris being collected over time* | | R | |
| 4 | Housekeeping is identified in work standards (standardized)? | Housekeeping tasks are defined in the work instructions | *Required cleaning materials and their locations are identified within the workplace organization* | | R | |
| 5 | Is the area included to the Plant 6S audit process | Check if area was audited and results | *Are there actions defined* | | R | |
| 6 | Are there white boards available for all information | Check for white boards | *Is the information updated* | | R | |
| 7 | Does management audit housekeeping and workplace organization(Sustain)? | Audit checklists and records of audits | *Shop floor documentation and results* | | R | |

| | | | | |
|---|---|---|---|---|
| | | **OK** | 0 | |
| **0** | No implementation or not existing: Corrective Action Required | | 0 | |
| **1** | Written implementation plan ready but not in use: Corrective Action Required | **NOK** | 67 | |
| **2** | In place, but not followed: Corrective Action Required | **0%** | | |
| **3** | YELLOW: Requirement partially implemented, minor improvement needed. | **Overall Result % yellow & Green** | | |
| **4** | GREEN: Requirement met | ***Acceptable = 70% in Yellow & Green*** | | |
| **NR** | NR: Not Reviewed | | | |

# Appendix 10: Updated ramp-up plans after process validation build evaluation

Output 1,0 = 90 pcs/crew

**PP18 Engine - 2 x 14 station conveyor - 16 weeks ramp-up**

| | 8hr crews per work day | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cw | 2225 | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 | 2240 |
| | Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| | Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| | Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| | Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Line1 | Output 1st crew - 30 day ramp-up | 12% | 25% | 39% | 57% | 78% | 95% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Line1 | Output 2nd crew - 30 day ramp-up | | | | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% | 100% | 100% |
| Line1 | Output 3rd crew - 30 day ramp-up | | | | | | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% |
| Line2 | Output 4th crew - 30 day ramp-up | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Line2 | Output 5th crew - 30 day ramp-up | | | | | | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% |
| Line2 | Output 6th crew - 30 day ramp-up | | | | | | | | | | | 12% | 25% | 39% | 57% | 78% | 100% |
| | Week production plan | 55 | 115 | 230 | 370 | 525 | 690 | 805 | 935 | 1015 | 1185 | 1440 | 1715 | 2020 | 2315 | 2560 | 2700 |
| | Day production plan | 11 | 23 | 46 | 74 | 105 | 138 | 161 | 187 | 203 | 237 | 288 | 343 | 404 | 463 | 512 | 540 |

Output 1,0 = 180 pcs/crew

**PP18 Bumper 8 station conveyor - 14 week ramp-up**

| 8hr crews per work day | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cw | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 |
| Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Output 1st crew - 30 day ramp-up | 12% | 25% | 39% | 57% | 78% | 95% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Output 2nd crew - 40 day ramp-up | | | | | | 8% | 18% | 30% | 60% | 75% | 87% | 96% | 100% | 100% |
| Output 3rd crew - 30 day ramp-up | | | | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% |
| Week production plan | 110 | 225 | 350 | 515 | 705 | 930 | 1065 | 1280 | 1670 | 1925 | 2195 | 2465 | 2660 | 2700 |
| Day production plan | 22 | 45 | 70 | 103 | 141 | 186 | 213 | 256 | 334 | 385 | 439 | 493 | 532 | 540 |

Output 1,0 = 180 pcs/crew

**PP18 Rearwall-conveyor 1x 6 station - 15 week ramp-up**

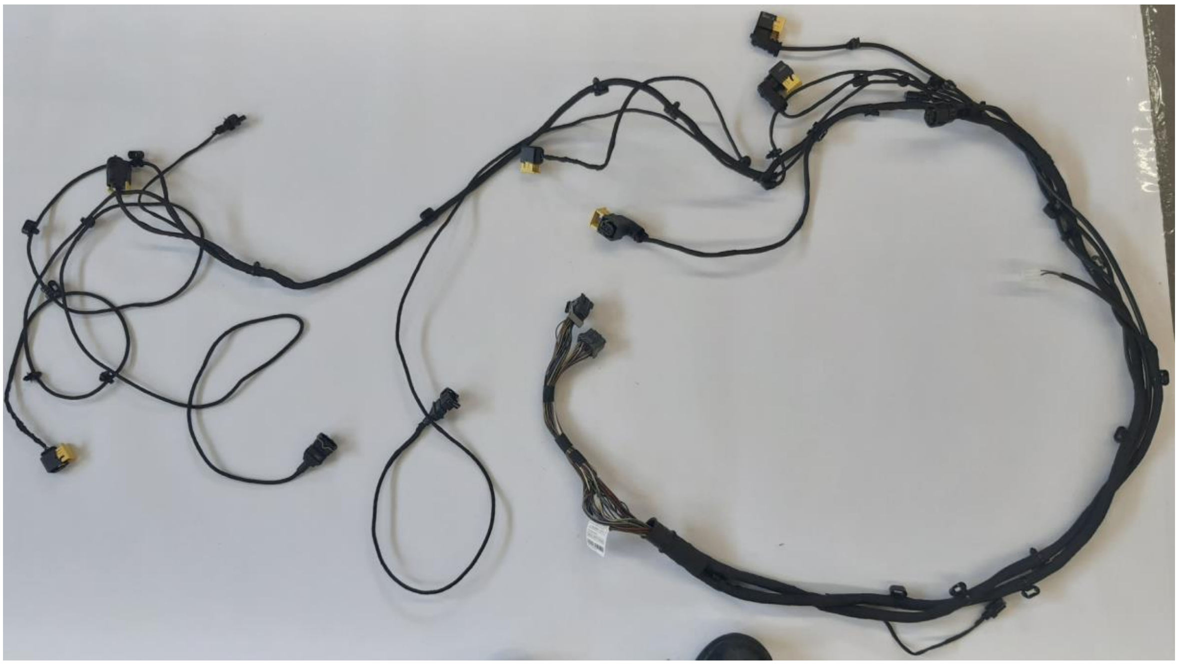
| 8hr crews per work day | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cw | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 | 2240 |
| Week customer order Aksaray | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| Week customer order Wörth | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 |
| Day customer order Aksaray | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| Day customer order Wörth | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Day customer order TOT | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |
| Output 1st crew - 30 day ramp-up | 12% | 25% | 39% | 57% | 78% | 95% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Output 2nd crew - 40 day ramp-up | | | | | | 8% | 18% | 30% | 46% | 60% | 75% | 87% | 96% | 100% | 100% |
| Output 3rd crew - 30 day ramp-up | | | | | | | | | 12% | 25% | 39% | 57% | 78% | 95% | 100% |
| Week production plan | 110 | 225 | 350 | 515 | 705 | 930 | 1065 | 1170 | 1420 | 1670 | 1925 | 2195 | 2465 | 2660 | 2700 |
| Day production plan | 22 | 45 | 70 | 103 | 141 | 186 | 213 | 234 | 284 | 334 | 385 | 439 | 493 | 532 | 540 |

# GRAPHICAL MATERIAL

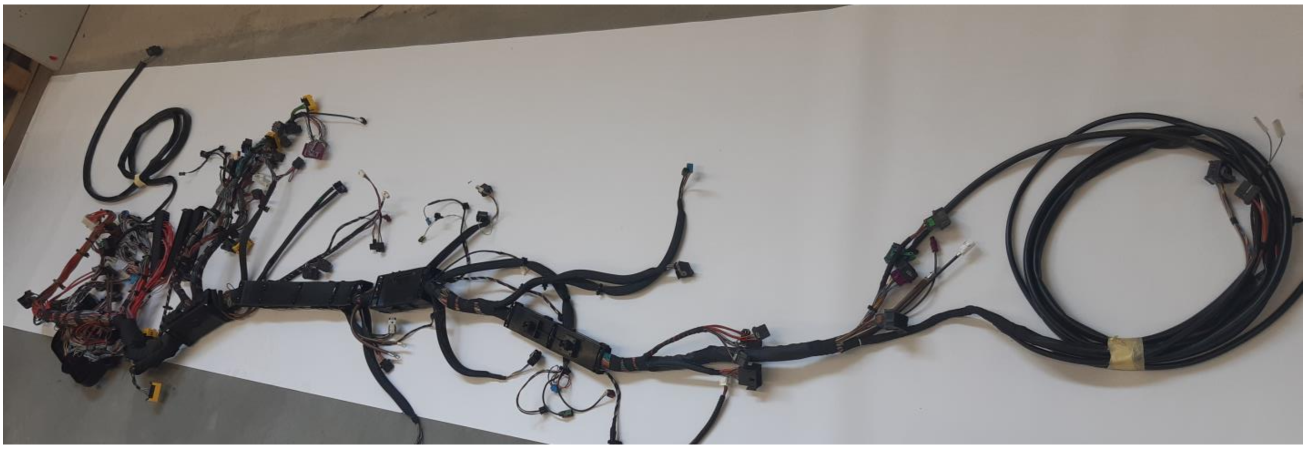
## Manufacturing unit


PKC Group wiring harness manufacturing plant, Curitiba, Brazil

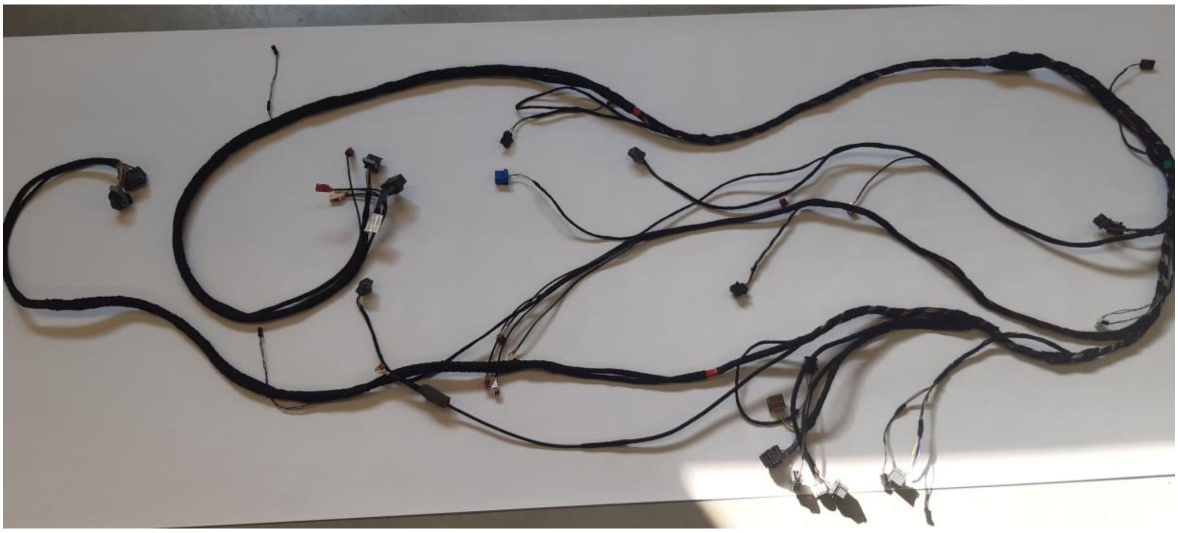
## Products



XVK82 front bumper harness for Daimler Actros truck [10]

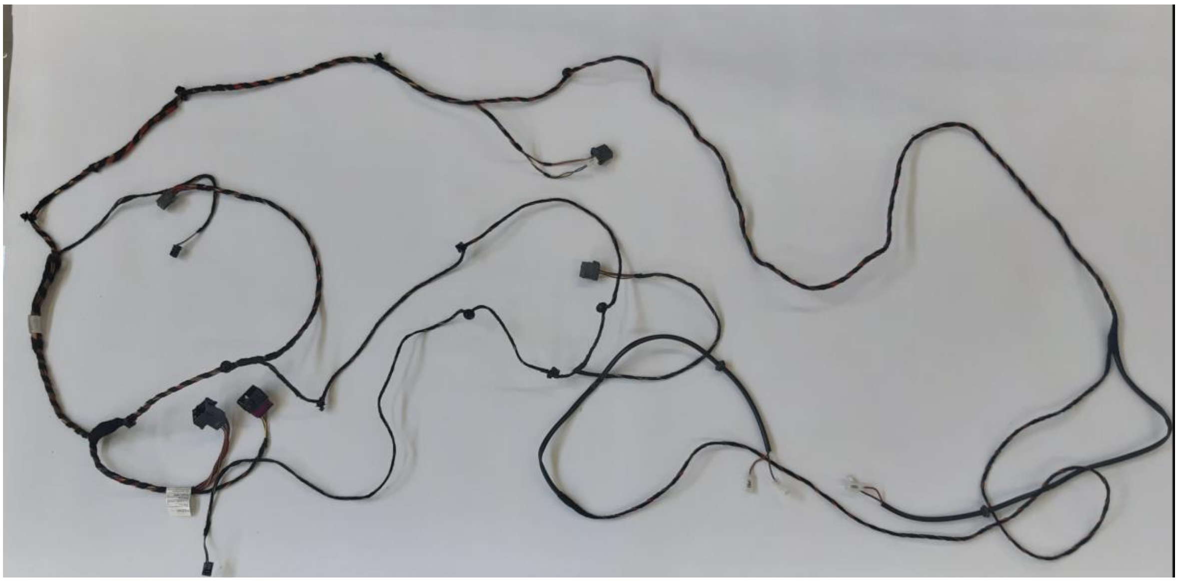


XVK84 dashboard harness for Daimler Actros truck [10]



XVK86 roof harness for Daimler Actros truck [10]

XVK87 door harness for Daimler Actros truck [10]

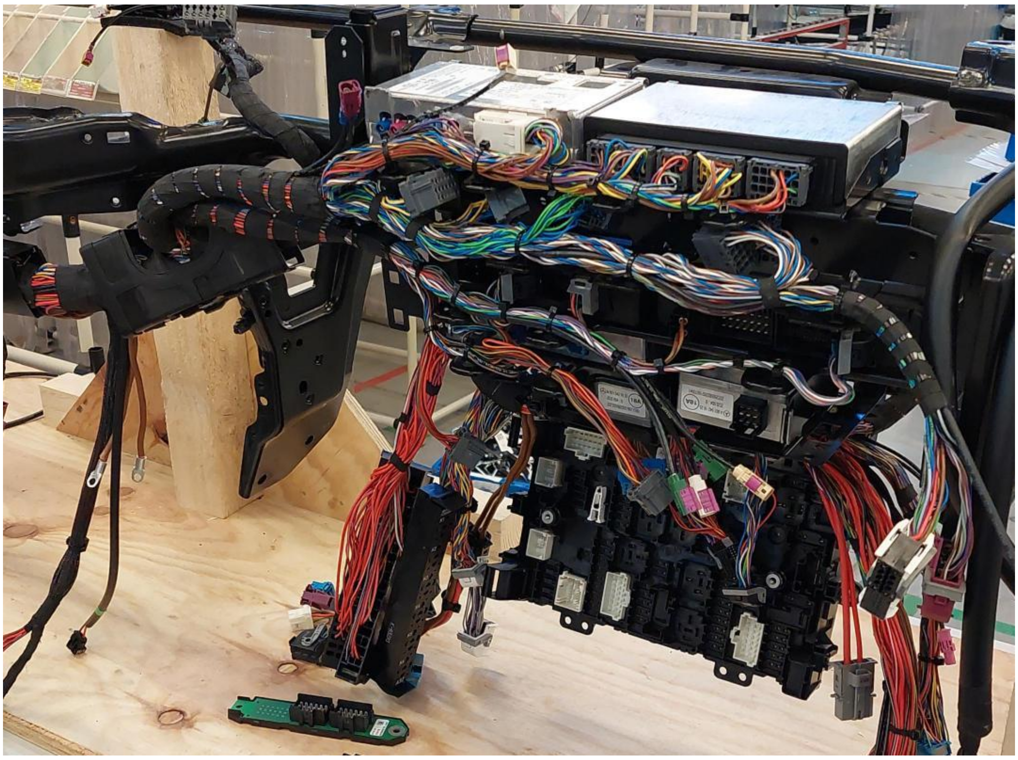

XVK89 rear wall harness for Daimler Actros truck [10]

# Images from shop floor

SFTP Front Bumper harness production area, PKC Smederevo factory [10]


FOT build workstation with product - XVK81 chassis harness for Daimler Actros truck [10]

FOT build workstation with product - XVK84 dashboard harness [10]



Fit test of dashboard XVK84 harness for Daimler Actros truck [10]

## Daimler Trucks – Actros and Arocs