Software Requirements Specifications

MANF\_O 555: Factory Planning

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# Introduction

Efficient production management is a key factor in the field of industrial engineering. Key to efficient production is a solid Manufacturing Execution System (MES). A production manager or production scheduler requires a place to build work orders, schedule labour, monitor inventory, and deploy orders to production. This document outlines a newly proposed MES to handle product creation on the cell phone production lab within the UBC Okanagan Manufacturing Lab in EME-2220.

Section 1 introduces the topic and the justification case for implementation, along with key functional objectives, literature references, and explanations of abbreviations and definitions utilized throughout the SRS. Section 2 covers the broad description of the product, why it is needed, and who interacts with it. Section 3 covers the specific functional and nonfunctional requirements of the product.

## Purpose

This software design document (SRS) aims to outline the functional requirements as set by the client *Consumer Co.* to be fulfilled by the developer *MES Design Inc.* Priorities of this document include:

1. Function as a letter of intent by detailing the collective interests of the client’s intention to commission the developer to produce a software-based Manufacturing Execution System (MES) for the client’s mobile phone assembly line.
2. Promote consensus, especially among potentially contentious aspects of the development, amongst the stakeholders & affected parties.
3. Provide clear descriptions and overviews of the proposed MES functions, objectives, architecture, utility, software requirements, and constraints to facilitate development
4. Clearly state the tool’s scope and assumptions used in its development.

## Client Background

The proposed MES is to be custom designed to support the client’s mobile phone assembly operations located in the Manufacturing Lab in room 2202 of the EME building at the University of British Columbia’s Okanagan Campus, located at 1137 Alumni Avenue, Kelowna BC V1V 1V7. *Consumer Co.* operates using a pull-demand supply chain, where products are made in response to customer’s orders. The client’s production line is comprised of eight modular Festo Mechatronics Learning Factory stations arranged linearly in a series eight-step manufacturing process with each module completing a unique task. Workpieces are transferred between each station through a conveying system, with each workpiece being carried on an RFID enabled pallet/carrier throughout the process. The plant only requires a single operator to run, who is regularly stationed at station 4. Simple descriptions of each station’s responsibilities are available in section 3.4. Although all stations include PLCs with intercommunication capabilities, the modules are currently siloed from each other, resulting in an underperforming manufacturing system that is difficult to optimize in its current state.

As of time of writing, the client’s assembly operation does not benefit from a centralized system to manage their WIP, material and information flow. The client does not have insight into their facility’s OEE, and overall process visibility is poor. They know that the rates of products failing quality control checks are rising, and that key KPIs such as FPFY and TSP are on the decline, but they are unable to pinpoint the origin of these losses. Leadership suspects this to be related to observed rises in customer order complexity, coupled with human-error due to the recent hiring of several new machine operators.

The client’s leadership team wishes to invest in production improvement technologies, but without reliable KPI metrics, leadership is unable to quantify the profitability of proposed production system upgrades, thus stalling upgrade proposals. Additionally, inventory management, production planning, and order processing are being manually performed in the absence of an MES. Due to forecasted growth in order volumes and complexity, automation of these processes will be critical for *Consumer Co.*’s next phase of operations.

Although *Consumer Co.* does not currently utilize an ERP, the company wishes for the proposed MES to be scalable, flexible, and able to be integrated into an ERP should future market conditions warrant the implementation of a broad, organization-wide resource planning tool.

## Scope

The proposed software solution to address the challenges described above in section 1.2 is to be named *Gateways MES (GMES),* with the final product application supporting the client’s growth in the custom built-to-order cell phone market while controlling headcount and administrative manufacturing costs. As such, the *GMES* will have the following responsibilities:

* Provide a UI that permits a user to input customer order information
* Execute mobile device assembly operations (goal is to minimize the amount of human interaction needed in assembly process)
* Alert the user when an error occurs during order execution
* Provide insight into operational KPIs, such as OEE, FPFY, TSP
* Manage production materials inventory, alerting users when inventories are low/depleted
* Retain key information for each product produced, such as:
  + Order details
  + Operator’s name or identification number
  + Date/time that the part completed each module of the production line
  + QC pass/fail results

*GMES* will not have the following responsibilities:

* Training modules for plant operation or maintenance
* Supply chains logistics (either incoming materials or final product deliveries)
* Payment processing
* Maintenance scheduling or planning
* Equipment & machinery maintenance spare parts inventory management
* A repository of equipment, facility, or material literature (i.e. O&M documentation)

## Reference Material

1. *Software Design Document (SDD) Template.* Richert, D. Faculty of Applied Sciences. Canvas.ca. Accessed October 1, 2024 [Online.] Available: *<*https://canvas.ubc.ca/courses/150390/files/34245948?module\_item\_id=7147139>
2. *MANF 455 – Factory Planning Manufacturing Execution Systems (MES).* Richert, D. Faculty of Applied Sciences. Canvas.ca. Accessed October 2, 2024 [Online]. Available: <https://canvas.ubc.ca/courses/150390/files/34740845?module\_item\_id=7147129>
3. "IEEE Recommended Practice for Software Requirements Specifications," in *IEEE Std 830-**1998* , vol., no., pp.1-40, 20 Oct. 1998, doi: 10.1109/IEEESTD.1998.88286.

## Definitions and Acronyms

* ACK – Acknowledge
* EME – Engineering, Management, and Education. A building at UBC Okanagan Campus.
* ERP – Enterprise resource planning. Organizational level software that manages a company’s core business processes.
* FPFY - First pass first yield: A metric detailing the percentage of manufactured goods that pass all quality control checks without requiring correction.
* GMES – Gateways MES: The proposed software to be developed.
* KPI - Key performance indicator
* MES - Manufacturing execution system: A software system that controls, overviews, manages, and documents a manufacturing process.
* OEE - Overall equipment effectiveness: The primary measure of the efficacy of a manufacturing process.
* O&M – Operations and maintenance
* PLC - Programmable logic controller
* QC – Quality control
* SRS - Software requirements specification: A document detailing software function and performance.
* SCADA – Supervisory control and data acquisition
* SYN – Synchronize
* TPS - Total saleable product
* UBC – University of British Columbia
* UI – User interface
* WIP - Work in progress: A manufactured good that has not completed all stages of a manufacturer’s value addition processes.

# Overall Description

This section provides a high-level overview of the MES, as well as its interactions with the full production system. It highlights how data will flow through the software to the greater ecosystem of the production line. It will then outline general functionality, and any constraints and assumptions to be held during development.

## Product Perspective

The MES is designed to allow for production management and error tracking on the cellphone production plant. This product will work in tandem with the PLCs within the cellphone production plant, providing user supplied information to direct the execution of the plant. It will be able to interface with the production system to facilitate ordering and customization of products.

Figure 1 below details the hierarchy of function execution once a production plan is actioned and the role of *GMES* in the system. Although *Consumer Co*. does not utilize management ERP software or supervisory SCADA systems, they have been included (but greyed), to illustrate their functional roles if they were implemented in future cases.

Figure 1: Role of GMES in Consumer Co.'s Organizational Structure

Figure 2 highlights how data will flow through the system. The order manager will be able to interact with the MES to place orders and monitor production. The MES will communicate with internal database, which will store inventory records as well as historical logs from production. When an order is placed within the system, the MES will communicate the order to the PLCs in the main production system.

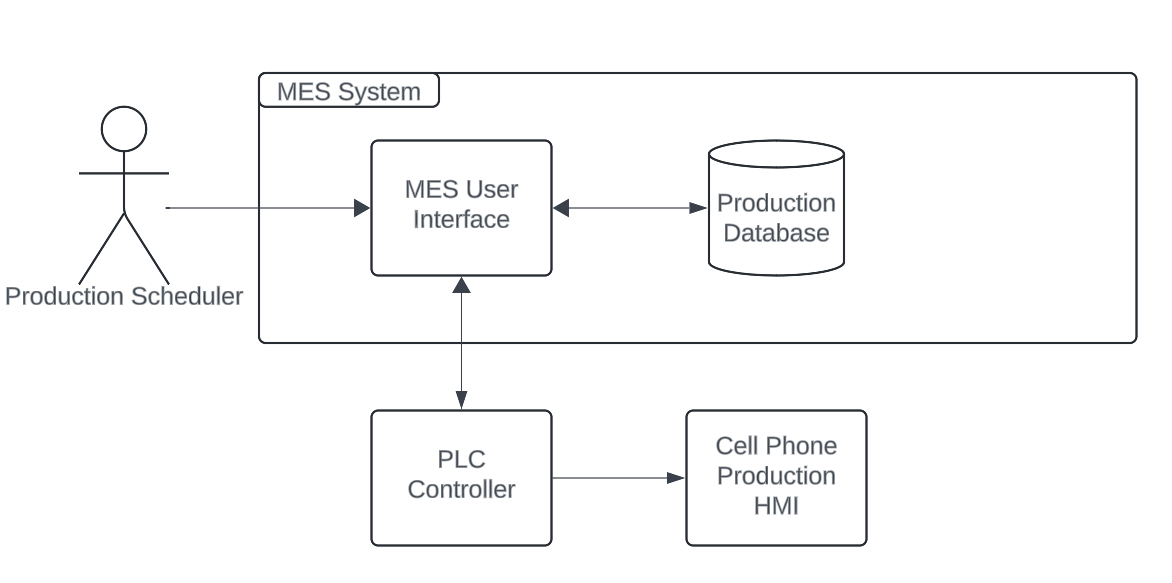


Figure 2: Data Flow Diagram

## Product Functions

The high-level goal of this program is to function as the primary way to control work on the cellphone production line. It is expected to schedule work, assign operators, and allow for product customization. The program will allow a user to access the production manager, check inventory levels, and manage operators. From there, operators can be assigned to production stations and assigned a schedule. Further, products can be scheduled to be produced. Product templates will be programable into the MES, which can be modified at order time. These templates outline what parts are required, and which parts are interchangeable. The key features are expanded on below.

Schedule Work Order: A user can build a work schedule, which includes machines available, processing time, and assigned operators.

Manage Inventory: A user can specify what currently exists in inventory and update it. Inventory is automatically updated based on scheduled orders.

Manage Operators: The software will allow for the creation of operators within the system, specified by name, id, and hourly rate. A manager can assign an operator to various roles and attach them to specific work orders.

Product Template Design: A product template consists of the materials required to make a product, as well as the machines and time required for it to be made.

Create Work Order: A work order is a defined order of product for a customer. One work order can contain multiple products. It acts as a collection of cost and material for the order.

Calculate OEE: The software will be able to track numerous factors of productivity to create a score on overall equipment effectiveness.

Track Downtime: The software will be able to interface with other parts of the system to track machine downtimes and backlogs.

## User Characteristics

A simplified labour organization structure of *Consumer Co.* may be observed in Figure 3. This structure does not include departments such as Human Resources, Finance, or other departments operating within the organization with distant responsibilities (i.e. a product research and development team). This figure demonstrates the different levels of the organization that may interface with the tool on a regular basis, with the Production Planner being the primary user,

Figure 3: Consumer Co.’s simplified organizational structure

*Gateways* *MES* is aimed to primarily be used by Production Planners within *Consumer Co*. The intended users are presumed to have college-level education and be knowledgeable of *Consumer Co*.’s manufacturing operations. Users are required to have a strong grasp of the English Language, as this is the sole language in which *GMES* will be offered. Users will not be required to possess technical knowledge of systems automation, software protocols, equipment O&M, PLC or computer programming languages.

Although the tool is primarily targeted towards Production Planners, there may be instances where other stakeholders will require using the tools. Examples of user cases and approximate usage volumes are shown in Table 1 below. *Consumer Co*. may decide to evolve these task delegations in *GMES* as the company gains experience with the software.

Table 1: Gateways MES (GMES) Projected Users

|  |  |  |
| --- | --- | --- |
| **Role** | **Frequency of use (****%)\*** | **Examples of targeted uses** |
| Production Planner | High >20% | Inputting production orders, scheduling and executing production runs |
| Operations Manager | Low <5% | Reviewing production batch KPIs, order and machinery configuration overrides. |
| Logistics Supervisor | Low <5% | Reviewing upcoming order information to schedule product delivery & material logistics in response to order demands |
| Operations Supervisor | Low <5% | Reviewing production batch KPIs, scheduling labour in response to production schedules, executing production runs |
| Maintenance Technicians | Extremely Low <1% | Troubleshooting machinery errors tied to MES order executions (technicians will **not** attempt to resolve software issues) |
| Sales Team | Low <5% | Inputting new customer information |

\*Frequency of use is defined as the estimated percentage of working hours that a particular employee group can expect to use the tool per year.

## Constraints

The development of *GMES* is subject to several constraints that will influence its design and implementation.

2.4.1. Regulatory policies

* Data privacy: the MES handles customer data so it must adhere to regulatory policies that govern data privacy.

2.4.2. Hardware limitations

* PLC and HMI hardware compatibility: The MES will be specifically designed for use with Siemens SIMATIC ET200 PLCs and TP700 Comfort. Any changes in hardware could lead to incompatibility.
* Workstation processing power: The reliability of the MES is dependent on the processing power of the workstation it runs on. If the workstation running the software does not meet the minimum hardware requirements mentioned in section 2.5, it could lead to poor real-time data processing, file corruption, a slow user interface, and potential errors in the assembly process.

2.4.3. Interfaces to other applications / communication protocols

* The MES will communicate with assembly hardware through the TCP/IP communication protocol. Hardware must be compatible with this communication protocol.

2.4.4. Parallel operation

* The software must support the ability for the user to add new orders to the MES while the plant is producing mobile devices.

2.4.5. Audit functions

* The MES will track the plant operator name, and record pass/fail results from each station for auditing purposes.

2.4.6. Signal handshake protocols

* The TCP/IP communication protocol relies on a three-way handshake (SYN, SYN-ACK, ACK) to establish and maintain reliable connections with assembly hardware.

## Assumptions and Dependencies

2.5.1. Assumptions

2.5.1.1. It is assumed that the assembly line hardware will remain fixed.

2.5.1.2. It is assumed only one work order can be processed at a time.

2.5.1.3. It is assumed that operators will operate solely over local network connections.

2.5.1.4. It is assumed that materials will be limited to those presented by the client in Table 2.

2.5.1.5. It is assumed that in event of an alarm going off, the system should stop production and enter an idle state.

2.5.2. Dependencies

2.5.2.1. The software will be designed to run on a workstation with windows XP or later.

2.5.2.2. The software will require to be connected to the plant system via a local wired connection.

# Specific Requirements

Below are the enumerated functional and non-functional requirements for the MES system. These ensure every requirement is covered by at least one-use case.

## Functional Requirements

3.1.1. The software must be able to generate and deploy work orders. A work order refers to a collection of tasks to complete a production for a specific client.

3.1.1.1. A work order must contain a list of components needed for completion.

3.1.1.2. A work order must contain a list of machines and time estimates required.

3.1.1.3. A work order should automatically populate time estimates from previous runs of each product.

3.1.1.4. A work order must contain a cost estimate based off the inventory required and the time estimate.

3.1.2. The software must be able to maintain a schedule for work orders and allow a user to modify the schedule.

3.1.2.1. The schedule must clearly show which work orders are currently scheduled alongside their time estimates.

3.1.2.1. Work orders will be given a priority based on required completion date and automatically placed into the schedule.

3.1.2.2. Work orders must be manually adjustable within the schedule.

3.1.2.3. If a work order is unable to be completed, it shall be removed from the schedule and its timeslot replaced with the next highest priority work order.

3.1.3. The software must be able to calculate relevant information to the production line, including OEE, FPFY, and TSP.

3.1.3.1. Overall Equipment Effectiveness (OEE) is one of the most fundamental performance indicators for a manufacturing operation, relating an operation’s availability, performance, and quality metrics. It is calculated as follows:

3.1.3.2. First Pass First Yield (FPFY) is a commonly used KPI that indicates the percentage of total conforming product that is produced that met all QC requirements without requiring rework. For the purposes of *Consumer Co*, it is assumed that all non-conforming products are discarded rather than reworked as a quality assurance measure. Given this assumption:

3.1.3.3. Total Saleable Product (TSP) quantifies the total amount of product produced that can be distributed to customers. It is expressed in terms of produced units (i.e. production volume) and is calculated as follows:

3.1.4. The software must be able to track downtime of machines

3.1.4.1. Downtime will be broken down into scheduled downtime, unexpected downtime, and idle time.

3.1.4.2. Scheduled downtime is defined as scheduled time a machine is out of operation.

3.1.4.3. Unexpected downtime is defined as time where the machine is down for any unplanned reason. It is logged from the point where an alarm is triggered within the PLC until the point in which the alarm is cleared and operation resumes.

3.1.4.4. Idle time is defined as the time in which a work order is being processed, but a specific machine is not in operation.

3.1.5. The software must be able to create, assign, and manage operators

3.1.5.1. Operators will be defined by a name, ID number, and hourly rate.

3.1.5.2. Operators must be able to be assigned to any machine or part of production.

3.1.5.3. Working hours of each operator must be tracked within and displayed within an operator overview.

3.1.6. The software must be able to create product templates which outline what is required for a product to be created.

3.1.6.1. The product template shall include all required materials and costs of materials based on current inventory.

3.1.6.2. The product template shall include all machines and machine time estimates required to make a specific product.

3.1.6.3. The time estimates to make a product will be averaged based on previous runs of production for a specific product.

3.1.7. The software must be able to track inventory and allocate it across work orders.

3.1.7.1. The software shall alert staff when parts are available for fewer than a specified threshold of units.

3.1.7.2. The software will automatically deduct items from internal inventory upon the start of a work order.

3.1.7.3. Inventory of a specific item can be manually adjusted and updated

3.1.7.4. The cost per unit of inventory items shall be stored and updateable.

## Nonfunctional Requirements

3.2.1 Performance

3.2.1.1 The system shall process changes to orders within 3 seconds with an order size below 100 units.

3.2.2 Reliability

3.2.2.1 The software must have an uptime above 95% over any 30-day period.

3.2.2.2 The software shall generate backup files at an interval specified by the user.

3.2.3 Scalability

3.2.3.1 The software must allow for multiple users to make changes to different work orders concurrently.

3.2.4 Usability

3.2.4.1 The software UI will be intuitive and clear with which inputs are required on each screen.

3.2.4.2 The software UI will be screen-reader friendly to allow for increased accessibility.

3.2.5 Security

3.2.5.1 The software will comply with all data storage requirements for user data.

3.2.5.2 Work order data will be encrypted and stored to protect order information.

## User Classes

The software will be broken down into two main user classes, with a “standard” user profile that is to be used by employees in the specialist classifications detailed within Figure 3, and an “administrator” role with higher privileges that is open to mid-level management employees (Operations Manager and higher, if required). The standard user profiles will have access rights to perform routine tasks such as inputting order data, adding new customers, executing orders, etc. The administrator role will be used to input new product specifications and varieties. This will reduce the risk of infeasible order requests (i.e. specifying part colours that are not available) from being executed, potentially leading to customer complaints and/or brand damage.

## Allowable Material Component Specifications by Station

*Gateways MES* will allow for order customization based on permitted system and product varieties, as defined by *Consumer Co.* These specifications are shown in Table 2.

Table 2: Station Descriptions and Station Component Options

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Station # | Station Name | Station Description | Installed Component Type | Component Variety |
| 1 | Magazine-Front | Dispenses a front cover to a carrier on a working conveyor | Front Cover | Blue |
| Red |
| Black |
| 2 | Measuring | Performs QC measurements on the front cover | - | - |
| 3 | Drilling | Drills simulated holes in the front cover for associated hardware | Holes Location and Quantity | 2x holes (Left side) |
| 2x holes (Right side) |
| 4x holes |
| 4 | Pick-by-Light | Manual operator station with digital instructions for parts installation to workpiece | PCB Selection | 1 x PCB |
| 0 x PCB |
| Fuses Selection | 0 x Fuses |
| 1 x Fuse (Front Case) |
| 1 x Fuse (Back Case) |
| 2 x Fuses |
| 5 | Magazine-Back | Dispenses a back cover onto the workpiece | Back Cover | Blue |
| Red |
| Black |
| 6 | Press | Tamps the workpiece to join front and back covers | - | - |
| 7 | Labelling | Applies information label to workpiece | - | - |
| 8 | Output | Transfers completed workpiece to output slide | - | - |