Systems Engineering Handout

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1. Stakeholder Analysis

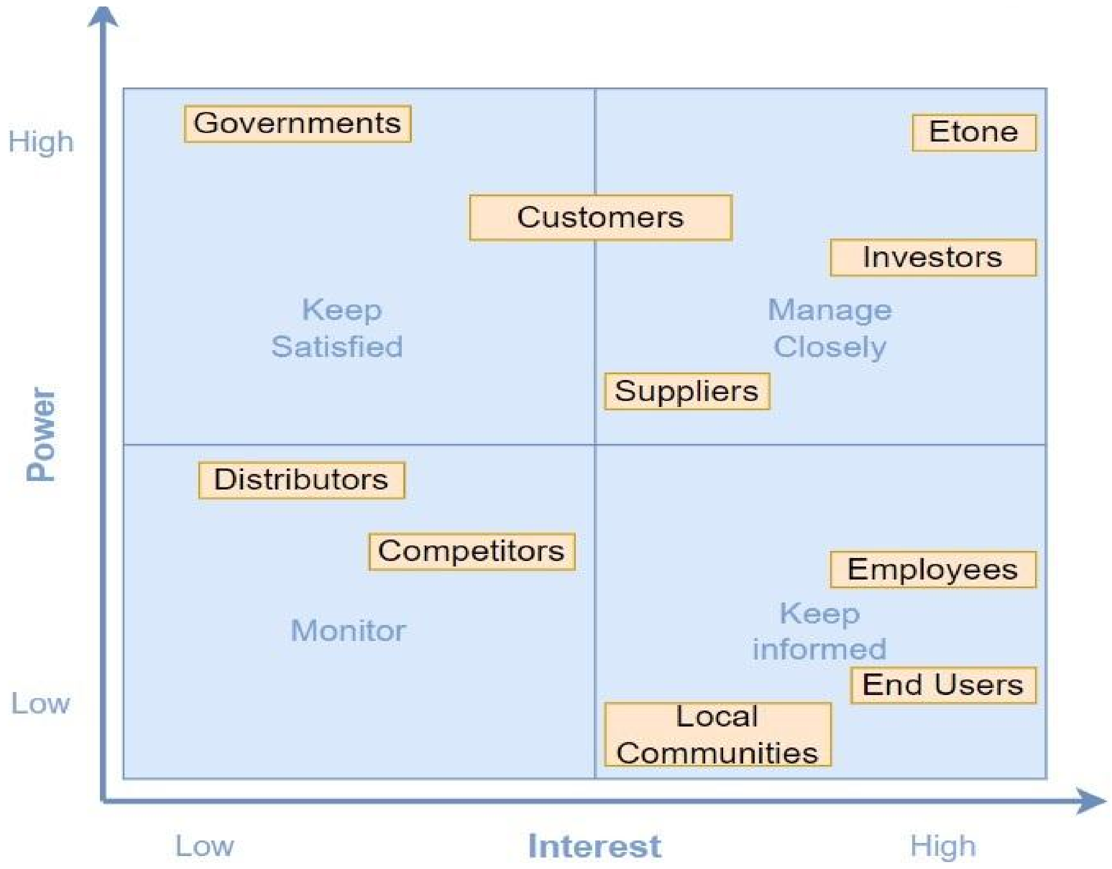

Figure 1: Stakeholder Power vs Interest

After performing the stakeholder analysis, several process key drivers have been established to each stakeholder in order to map their requirements as can be seen in figure 2. The Employees, End Users and Local Communities were excluded from this diagram since their requirements of sustainability and safety are already set by the government so no additional key drivers have been set for them. Etone needs to make sure that their distributors are reliable and it was assumed that products are delivered right away so they were also excluded. Additionally, Etone only needs to monitor their competitors so they have also been excluded from the key driver- stakeholder mapping diagram as well.

2. Key Driver - Stakeholder Mapping

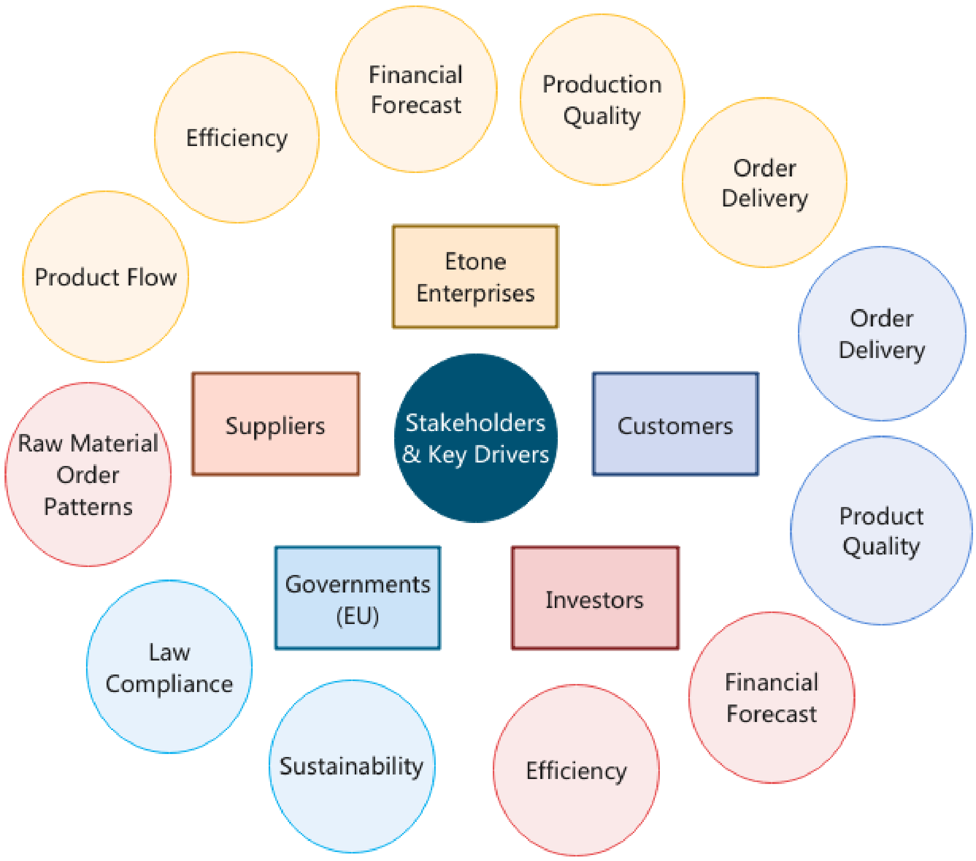

Figure 2: Key Driver - Stakeholder Mapping

For each stakeholder, the most important system parameters were identified as key drivers and for each key driver, several functional requirements have been identified as can be seen in the poster. Additionally, general non functional requirements have also been determined for the systems in order to quantify the general functionality of the entire production system.

3. FunKey Coupling Matrix

Function	Key Driver							
	kd1	kd2	kd3	kd4	kd5	kd6	kd7	kd8
F1	X		X		X	X	X	
F2	X				X	X	X	
F3	X			X	X			
F4	X	X			X			X
F5	X	X	X	X	X	X		X

Table 1: System Function - Key Driver Coupling

kd1 : Raw Material Order Pattern
kd2 : Product Flow
kd3 : Efficiency
kd4 : Financial Forecast
kd5 : Product & Production Quality
kd6 : Order Delivery
kd7 : FEM Analysis
kd8 : Legality & Sustainability

F1 : Sequence & Schedule Production
F2 : Manage Inventory
F3 : Monitor Finance
F4 : Generate Layout
F5 : Monitor Production

4. Subsystems Explained

Production Planning & Control (PP&C)
Schedule production including predicted maintenance time based on the data in the excel. Production Schedule includes production sequence for the delivery of the end product. They take into account the startup defects as well. This is the planning part.

They get input from QC&RM about the preventive and corrective protocol and implement that in the production schedule when there are defects creating an adjusted schedule. This is the control part. The control part consequently affects the finance and inventory part.

Finance & Inventory Management (F&IM)
They receive the production schedule from PP&C as well as land requirement from PF&D. They create a list of raw materials, new machines and staff needed as well as new floor space and use that for cost prediction as well as Inventory Management and warehousing. They determine when material orders should be placed and how much is needed.

Production Flow & Design (PF&D)
They receive information about the production schedule and sequence from PP&C and warehousing information from F&IM in order to create the optimum floor plan layout so that interdependent machines are grouped in order to minimize the ide time while keeping in mind the safety of the floorplan layout and keeping enough space for inventory. This is their initial role. Their continuous role is monitoring the product flow between the different production steps and ensuring that the unfinished product batches are moved to the correct stations on time so that the finished product can be completed in time to meet the delivery schedules.

Quality Control & Risk Mitigation (QC&RM)
They receive the inputs from the different subsystems and do a risk and FMEA analysis. They maintain quality control based on statistical models by deriving a preventative and corrective protocol (including maintenance strategy) in case failure occurs during production. They present the FEM analysis of the cranes since this can be seen as a risk preventative method for ensuring the end product quality is met.

The preventative protocol from QC&RM is given to the different subsystems again so that they can reimplement it in their subsystems. This mainly concerns PP&C and F&IM so they redesign the production schedule and inventory by implementing the maintenance strategy and keeping a safety stock in the warehouse in order to lower the risk of inactive operations.

5. Subsystem-KPI Mapping

Subsystem	Functional KPI
Production Planning & Control (PP&C)	1.1 Standard Working hours 2 shifts/day, 48 weeks/year 6.1 OEE >= 90% overall 8.1 Order batches should be produced at least 1 day before the required delivery date
Production Flow & Design (PF&D)	1.3 Safety exits at least 0.7 m wide 4.1 Walking distance < 2 m 4.2 Product Transit Time/Production Time < 0.13 4.3 Total idle time < 10% of the total production time
Finance & Inventory Management (F&IM)	1.2 Minimum Working wage 3.1 Cost of new machines < €40, 000 3.2 Breakeven point reached in 5 years 5.1 Regular and reliable raw material order patterns with a < 10% variation 5.2 Safety Stock < 5%, not more than 5% of the ordered raw materials is unused
Quality Control & Risk Mitigation (QC&RM)	2.1 Less than 5% wasted product and material 6.2 Cpk > 1.5 6.3 Machine startup defects < 1% per machine 6.4 Average scrap < 5% per machine 6.5 Downtime < 8 hours 7.1 Number of defective products per batch is less 2% of the total products per batch 7.2 For the STS cranes horizontal displacement of boom tip <= 4mm

Table 2: KPI to Subsystem Mapping

6. Subsystem Test Description

There are 19 Functional KPIs and 5 nonfunctional KPIs which were defined for our Production system. The functional KPIs have been defined to each subsystem while the nonfunctional KPIs deal with the overall functionality and integration of the production system. To verify and validate that the production system meets the defined system requirements we carry out unit testing as well as integration testing. Therefore, two test protocols have been defined where protocol (1) tests the subsystems separate functionality according to the functional requirements while protocol (2) tests that the interaction between the subsystems are efficiently carried out leading to the fulfillment of the nonfunctional requirements. The test protocol descriptions are outlined below.

Test Protocol 1: Unit Testing

The protocol consists of multiple tests where each test consists of subtests that concern a functional KPI. The KPIs are stated with the numbers defined in table 2 in bold followed by the suitable test description.

Test 1: Documentation Inspection
Test 1.1: [for requirement **1.1**] The working hours of the machines and workers should be documented and should not exceed the standard period. Monthly checkups of these documentations should be made.
Test 1.2: [for requirements **1.2**, **3.1** and **3.2**] The financial books should be inspected in order to ensure that minimum wages are paid and that the breakeven period can be reached within 5 years by comparing the revenues and expenses and doing the necessary adjustments.
Test 1.3: [for requirement **5.1**] The customer demand should be forecasted, and the raw material orders should be planned accordingly. Since the annual customer demand is known by Etone, the raw material order patterns should be reliable and should not have high fluctuations. This is documented and checked and should be ensured by proper production planning.

Test 2: Floor Inspection
Test 2.1: [for requirements **1.3** and **4.1**] The floorspace will be inspected before the start of production to make sure that the layout meets the requirements and matches the blueprints of the factory.
Test 2.2: [for requirement **8.1**] Finished orders should be reported and the order progress should be checked regularly to make sure that it is completed within the specified time
Test 2.3: [for requirement **5.2**] The amount of stock left in the warehouse at the end of the month should be calculated and compared to the amount of the raw materials ordered. If this is more than 5%, this should be reported, and the order patterns should be adjusted.

Test 3: Efficiency Check
Test 3.1: [for requirements **4.2**, **4.3**, **6.1** and **6.2**] The total production time should be estimated taking into account the amount of rework that needs to be done and machine idle time. The machines should be arranged and grouped in a way that minimizes the walking distance between the machines and product idle time so that the partly finished products can be moved to the next station as soon as possible. Several iterations and layouts can be made to ensure that this is achieved. This is theoretically tested before the start of production and planning of the factory layout. It is then confirmed during production by keeping track of the effective production time and performing the necessary adjustments.

Test 4: Quality Check
Test 4.1: [for requirement **6.3** And **6.4**] Average scrap per machine and machine startup defects should be calculated after each week and should be less than the values mentioned by the manufacturer. If they exceed these values, maintenance should be performed, or the machine should be replaced.
Test 4.2: [for requirement **6.5**] A comprehensive maintenance protocol should be written, and regular machine checkup should be made every 2 months so that the downtime is reduced.
Test 4.3: [for requirement **7.1**] Five random parts from each completed batch should be visually inspected for any defects and the dimensions should be measured. If the parts are defective this batch should be reproduced.
Test 4.4: [for requirement **7.2**] A crane should be tested with maximum load after assembly and the actual horizontal deflection should be measured to ensure that it is less than 4mm.

Test 5: Waste Check
Test 5.1: [for requirement **2.1**] The scrap rate and number of defective parts from the quality check test should be reported. This is checked every 2 months in order to ensure that it is kept to a minimum.

Test Protocol 2: Integration Testing

The production system can be simulated by creating a virtual test environment similar to the actual production environment. The outputs and inputs of each subsystem should be clearly defined and multiple iterations can be made using different scenarios by altering the parameters of the system to ensure that the relations between the subsystems are efficiently defined and that failures are minimized by minimizing the subsystem interdependencies. This is done before implementing the production system in real life. After the production system is implemented, the subsystems interactions should be carefully monitored and any errors or delays should be reported to the system engineers so that the necessary role re-definitions can be made in order to ensure that the production system is efficient, reliable, flexible, maintainable and cost effective.