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Risk mitigation action of sport shoes supply chain using the House of Risk Method

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ABSTRACT

PT PWI, a foreign capital company from South Korea, specializes in manufacturing Adidas and Reebok brand sports shoes. Throughout its supply chain activities, the company often faces challenges and risks, particularly delays in raw material deliveries from suppliers, which can significantly disrupt the production process. Hence, implementing risk mitigation actions becomes essential to alleviate these risks within the supply chain flow. This study aims to identify potential risk events and their agents, proposing strategies for risk mitigation. The House of Risk (HOR) method is employed, while the determination of business process criteria relies on the dimensions of the Supply Chain Operation Reference (SCOR). The study's outcomes include various risk mitigation measures, such as preparing backup suppliers, establishing agreements with suppliers (including compensation costs), implementing regular machine maintenance, enforcing stricter employee supervision, conducting more routine employee briefings, incorporating silica gel into each shoe, applying anti-mold spray to every shipment, implementing new rules for material retrieval using receipts, and enhancing raw material ordering plans and scheduling.

1. Introduction

PT PWI, a South Korean foreign capital company specializing in the manufacturing of Adidas and Reebok brand sports shoes for export to various countries, has been operational since 2016. The company, which heavily relies on its supply chain in its production process, faces numerous obstacles and risks that can impede its activities [1]. Delays in raw material deliveries from suppliers stand out as a critical issue currently affecting PT PWI's supply chain flow. Such delays not only disrupt the production schedule but also cause subsequent delays in product delivery to customers, leading to potential financial losses due to compensation costs. This demonstrates how a single problem or risk within the supply chain can trigger a chain of consequential risks.

Supply chain refers to a series of activities involving entities or facilities responsible for transforming and distributing goods from raw materials to finished products consumed by end-users [2]. It encompasses aspects such as raw material inventory, production, distribution, transportation, and more. Risk, as per the Australian/New Zealand Standard Risk Management, involves the possibility of events that can have both positive or negative impacts on specific objectives, measured based on likelihood and consequences. Risks within the supply chain manifest across suppliers, factories, to downstream distributors and consumers, representing uncertainties about future circumstances [3], [4]. While risks cannot be entirely avoided, proper risk management can minimize or eliminate their impacts. Often, a single risk event can trigger multiple risks [5], [6].

In the realm of supply chain processes, collaboration with upstream and downstream partners is vital to jointly mitigate undesirable risks throughout the supply flow. Supply chain risk, defined as disruptions damaging business processes, remains an ever-present challenge [7]. However, through effective risk management, these risks can be reduced or prevented. Thus, implementing supply chain risk management (SCRM) becomes imperative.

Supply chain risk management involves systematically identifying, assessing, and mitigating potential disruptions within the logistics network to minimize adverse impacts on its performance [8]. The risk management process typically comprises four key

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activities: risk identification, assessment, decision-making, and implementing risk management activities, followed by risk monitoring [9].

This study aims to identify risk events, their sources (Risk Agents), and propose mitigation strategies. Employing the Supply Chain Operation Reference (SCOR) and House of Risk (HOR) methods, the SCOR method measures and enhances the total performance of the company's supply chain [10], [11], [12]. The HOR method, derived from a modification of FMEA (Failure Modes and Effect Analysis) and House of Quality (HOQ), prioritizes risk agents, enabling effective actions to mitigate potential risks [13].

The identification of risk events and risk agents at PT PWI involves conducting company interviews and employing the SCOR approach, considering Source, Make, Deliver, and Return factors. Severity and occurrence levels of risk events and agents are determined through brainstorming sessions with the company.

Utilizing Pareto diagrams and the House of Risk (HOR) phase 1 method, priority risks at PT.PWI are determined. Subsequently, mitigation actions are devised using the Effectiveness to Difficulty (ETD) calculation in the House of Risk (HOR) phase 2 method.

Previous research on supply-chain risk management has explored various strategies, including approaches such as the House of Risk for assessing risk management strategies [14], mitigating risks in businesses such as the Mangosteen industry [15], mitigating risks in the production process of packaged fruit juice drinks [16], assessing risks in maritime supply chains [17], and conceptualizing community in disaster risk management [18].

2. Material and method

The data collection for this research involved interviews, observations, and questionnaire administration. Employing a descriptive qualitative approach, the research methodology commences with problem identification—identifying the issues or risks faced by PT PWI across its supply chain flow. PT PWI's supply chain includes procurement, purchasing, manufacturing, warehouse, transportation sections, and customer users. The research encompasses stages of risk identification, analysis, evaluation, and mitigation.

The House of Risk 1 (HOR 1) model is employed from the identification to the evaluation stage, while the mitigation stage utilizes the HOR 2 model. The study commences by mapping PT PWI's supply chain, followed by determining the fundamental supply chain processes using the SCOR (Supply Chain Operation Reference) model, incorporating the five core stages: plan, source, make, deliver, and return.

2.1. Mapping supply chain sports shoes

The complete mapping of the sports shoe supply chain at PT PWI is shown in Fig. 1. The supply chain risk management stage carried out consists of risk identification, risk analysis, risk evaluation and risk mitigation. House of Risk (HOR) stages in supply chain risk management namely risk identification, risk analysis, risk evaluation dan risk mitigation.

2.2. Risk identification

At this stage, the focus is on identifying risk events (risk events) and their causes (risk agents), both those that have occurred and those with the potential to occur within the supply chain activities. The risk identification phase involves conducting field surveys and interviews to comprehensively identify potential risks. Specifically, at this stage, risk identification is conducted through interviews with employees working in the Supply Chain sector at PT PWI.

2.3. Risk analysis

In the second stage, the risk analysis employs the Supply Chain Operations Reference (SCOR) model approach and the House of Risk (HOR) method. The SCOR model approach is utilized to map supply chain activities, encompassing planning and sourcing. This stage incorporates the Failure Mode Effect Analysis (FMEA) method for risk assessment. Here, risks are measured considering their potential occurrence, evaluating the severity of disruptions and the frequency of the risk source. Subsequently, a correlation assessment between the risk event and the risk source (risk agent) is conducted to determine the Aggregate Risk Potential (ARP) value for each risk source. This stage utilizes the HOR 1 model.

2.4. Risk evaluation

The research commences by mapping the supply chain of PT PWI and subsequently engaging in the supply chain risk management process. This involves a sequence from risk identification, risk analysis, risk evaluation, to risk mitigation, evaluating the occurrence, severity, and correlation of risk events and risk agents. The HOR 1 model is utilized in this stage.

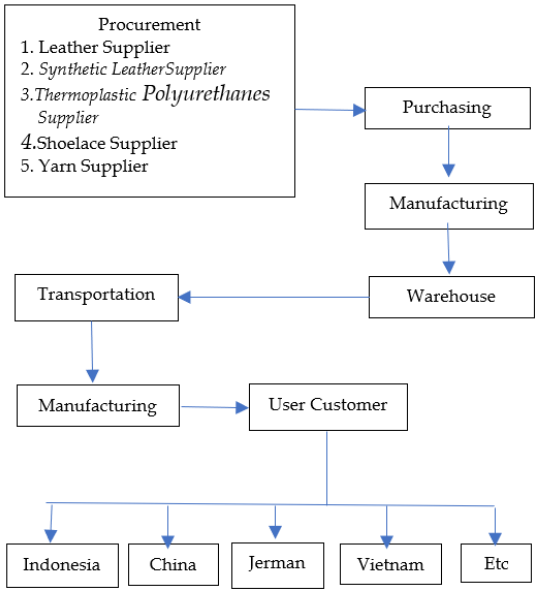

Figure 1. Supply chain sports shoe PT PWI

2.5. Risk mitigation

At this stage, the HOR 2 model is utilized to devise risk mitigation strategies aimed at minimizing risk consequences and preventing their occurrence. It involves prioritizing risk control measures based on the highest total effectiveness value.

3. Results and discussions

The research initiated by mapping the supply chain of PT.PWI and subsequently conducts the supply chain risk management process, involving stages such as risk identification, analysis, evaluation, and mitigation.

3.1. Analysis of supply chain

The supply chain system at PT PWI spans from upstream to downstream, encompassing suppliers, manufacturers, distribution, retail, and end customers. PT PWI sources materials from a total of five suppliers, which include two imported suppliers and three local suppliers providing leather, synthetic leather, TPU, shoelaces, and yarn. These materials undergo various production stages—material setting, cutting, subcontracting, sewing, assembling, finishing, inspection, and packing—before reaching the warehouse as finished goods. From there, the products are distributed to retailers and end users. PT PWI's transportation system employs the services of 3PL (Third Party Logistics) companies such as DHL and PLS for product shipping. The end customers of PT PWI are situated across multiple countries, including Indonesia (Sport Station), China, Germany, Vietnam, among others.

3.2. Risk identification

The process of risk identification utilizes the SCOR method's five main indicators: plan, make, source, deliver, and return. This identification process involves observation, interviews, and brainstorming sessions with the company to obtain a comprehensive understanding of the existing risks. The outcomes of the risk identification conducted at PT PWI are presented in Table A1 (see Appendices). Table A1 illustrates major processes categorized into five main indicators: plan, make, source, deliver, and return, along with corresponding risk events or issues within the supply chain system. A total of 12 identified risks could potentially lead to failures in the supply chain system.

3.3. Risk analysis

After the identification of risks using the SCOR method, the subsequent step involves analyzing these risks utilizing the HOR (House of Risk) method. The severity value is determined through interviews conducted with the company to complete a severity questionnaire based on the existing risk events. These events are linked to major processes—plan, make, source, deliver, and return—and associated sub-processes within PT PWI's supply chain system. The table provides a unique code for each risk event, and the severity assessment of these risk events is presented in Table 1.

The Severity of Risk Event shown in Table 1 serves as the initial stage in risk analysis, providing a ranking based on the potential impact of the event on the company's operational processes. The scale ranges from 1 to 10, where 10 represents the most severe impact. In this context, severity values are determined through collaborative brainstorming sessions with the company. The highest-ranking Risk Agent event is the delay in raw materials from foreign suppliers, scoring a value of 9 due to its significant impact on the business processes if it occurs.

The Occurrence of Risk Agent indicates the likelihood of the Risk Event's cause occurring and resulting in failure while the assets are in use. The scale also ranges from 1 to 10, with 10 indicating frequent occurrences in business activities. In Table 2, occurrence values are derived from collaborative brainstorming with the company. The highest-ranking Risk Events include Supplier overload, delays in materials from overseas suppliers, and careless operators, each scoring a value of 8. These risks are observed to occur quite frequently within business processes.

Table 1.
Severity of risk event

Risk event	Kode	Severity
Sudden change in production plan	E1	6
There is a delay in raw materials from overseas suppliers	E2	9
There is a mismatch of raw materials received from suppliers	E3	6
The quality of raw materials decreases	E4	5
Mismatch between the recorded and actual stock of raw materials in the warehouse	E5	7
There is 1 warehouse that lacks raw materials	E6	6
Color error	E7	5
Production delay	E8	9
Machine breakdown	E9	8
Defective product	E10	6
Moldy products during shipment	E11	8
The company pays fines due to defective products	E12	5

Table 2.
Occurrence of risk agent

Risk event	Kode	Severity
Customer requests that change sports shoe models	A1	5
Supplier overload	A2	8
Supplier error	A3	5
Raw material manufacturer error	A4	4
Taking material is not according to SOP	A5	7
Plan & scheduling that has been made is not effective	A6	6
Color similarity in storage baskets	A7	3
Delay in material from overseas suppliers	A8	8
Less routine machine maintenance	A9	5
Operator who is not careful	A10	8
Damp warehouse and shipping transportation	A11	7
Customer asked for compensation to the company because of defective products	A12	4

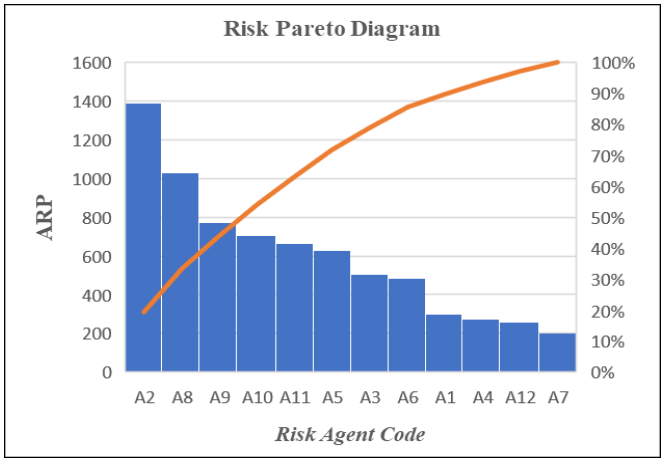

Figure 2. Risk pareto diagram

3.4. Risk evaluation

In this stage of risk evaluation, prioritization of risk agents for further risk prevention is determined based on the Aggregate Risk Potential (ARP) value. The ARP value acts as a reference and input to ascertain the priority of addressing the risk agents. Sorting the ARP values from the largest to the smallest helps analyze them using a Pareto chart [20]. The ARP value is derived from the correlation between the risk agent and the risk event, which is then mapped into the HOR 1 (House of Risk 1) matrix, as illustrated in Fig. B1. (see Appendices).

In the first stage of the House of Risk matrix, depicted in Fig. B1, the correlation value between the risk agent and the risk event is determined, which subsequently influences the ARP value. Table A2 showcases the ranking of ARP values obtained. Following the sorting of ARP values from the largest to the smallest, the results are visually represented in the Pareto diagram presented in Fig. 2.

Following the ranking of ARP values and Pareto diagrams for risk agents, 8 risk agents have been identified as priorities for risk mitigation. This selection is based on the cumulative percentage reaching approximately 80%. This aligns with the Pareto principle, signifying the 80:20 rule, where 80 percent of risk problems stem from 20 percent of the causes of risk. Thus, selecting risk agents that constitute 80% is presumed to encompass most risk sources [21].

Out of the 8 identified risk agents in the table above, risk mitigation or prevention strategies will be executed using the House of Risk stage 2. As depicted in Table A3 (see Appendices), the HOR 2 stage is aimed at devising risk mitigation strategies to prioritize effective and efficient risk prevention actions to be implemented by PT PWI.

Referring to the table above, the prioritized risk agents include A2, A8, A9, A10, A11, A5, A3, and A6. These eight risk agents contribute to the 80% cumulative percentage of ARP, aligning with the Pareto concept where 80% of Risk Agents lead to 20% of Risk Events. Hence, these selected risk agents are earmarked for improvement. Based on the Pareto diagram's 80-20 principle, signifying that 80% of Risk Agents cause 20% of Risk Events, the selection of risk agents A2, A8, A9, A10, A11, A5, A3, and A6 is grounded on their inclusion within the 80% threshold of Risk Agents. These risk agents are prioritized for mitigation efforts, forming the foundation for the subsequent risk mitigation stage.

3.5. Risk mitigation

After data processing with the HOR 1 method, we initiate risk mitigation actions with HOR 2. This step involves calculating total effectiveness, determining effectiveness ratios, assessing difficulty levels, and proposing risk mitigation strategies for PT PWI. In the House of Risk phase two, mitigation actions are established to minimize the impact of the identified risks. The initial step involves identifying ideal mitigation actions to address the priority risk agents previously determined.

Next, the ideal mitigation action (PAk) to resolve the issues related to the prioritized risk agents is determined. Table illustrates 3 the mitigation actions that PT PWI will implement. Table 4 presents nine mitigation actions aimed at minimizing the identified priority risk agents. Following the identification of these actions, the subsequent step involves measuring the correlation value (Ejk) between these mitigation actions and the prioritized Risk Agents.

Tabel 3.
Priority of risk agent

Code	Risk Agent
A2	Supplier overload
A8	Delay in material from suppliers
A9	Less routine machine maintenance
A10	Careless operators
A11	Humid warehouse and shipping transportation
A5	Material collection is not according to SOP
A3	Supplier error
A6	Plan & scheduling that has been made ineffective

Tabel 4.
Priority agent risk mitigation actions

Code	Mitigation Action
PA1	Set up a backup supplier
PA2	Make agreements with suppliers
PA3	Machine maintenance is carried out regularly
PA4	Stricter supervision of employees
PA5	Briefing employees more regularly
PA6	Adding silica gel to each shoe
PA7	Spraying anti-mold spray on every shipment
PA8	Make new rules for using receipts when taking materials
PA9	Make a better plan and scheduling for ordering raw materials

The correlation value scale mirrors the correlation between Risk Agent and Risk Event, encompassing the numbers 0, 1, 3, and 9. These values denote no correlation, low, medium, and high correlations respectively. To calculate the total effectiveness (TEk), the results of multiplying the correlation value (Ejk) with the ARP of each prioritized risk agent are aggregated.

Next, the degree of difficulty (Dk) is measured, which indicates the level of difficulty in taking mitigation action steps. The degree of difficulty is classified into 3 categories, namely easy to implement with a score of 3, moderate to implement with a score of 4, and difficult to implement with a score of 5 [22]. The last step is to determine the value of the difficulty to effectiveness ratio (ETD) by dividing the total effectiveness value by the degree of difficulty. The higher the ETD value, the more ideal the mitigation action is. Prioritizing the implementation of mitigation strategy is to determine alternative risk mitigation assessment that can be implemented by concerned the limitation of cost, human resources, and other aspects of the company [23].

3.6. Managerial implications

The managerial implications stemming from the research findings indicate that PT PWI can address risk agents contributing to various risk events within the sports shoe supply chain. Prioritizing and implementing mitigation actions can ensure a smoother flow along the supply chain. However, a notable limitation of this research is the absence of implementation due to constraints in time, cost, and personnel. Future studies are encouraged to focus on the practical execution of the proposed mitigation actions based on established priorities.

4. Conclusions

The research findings encompass 12 identified risk events and 12 corresponding risk agents. Among these, 8 priority risk agents necessitate mitigation measures. These include supplier overload, material delays from suppliers, irregular machine maintenance, operator negligence, warehouse humidity affecting shipments, non-compliance with material retrieval SOPs, supplier errors, and ineffective planning and scheduling.

Nine mitigation actions have been proposed for implementation, comprising the preparation of backup suppliers, agreements with suppliers to cover compensation costs, regular machine maintenance, enhanced employee supervision, more frequent employee briefings, addition of silica gel to each shoe, anti-fungal spray application on shipments, revised material retrieval protocols, and improved raw material ordering plans and scheduling.

Declaration statement

Maria Ulfah: **Conceptualization, Resources, Methodology, Supervsion, Writing-Original draft.** Dyah Lintang Trenggonowati: **Validation, Formal analysis.** Lely Herlina: **Data Acuration, Validation, Writing- Review & Editing**. Yusraini Muharni: **Writing – Review & Editing**.

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The authors report there are no competing interests to declare.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article or its supplementary materials.

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Appendices

Table A1.
Identification of risks with SCOR analysis

Major Process	Sub Process	Risk Event	Code	Risk Agent	Code
Plan	Production planning	Sudden change in production plan	E1	Customer requests that change sports shoe models	A1
Source	Delivery of raw materials from suppliers	There is a delay in raw materials from overseas suppliers	E2	Supplier overload	A2
		There is a mismatch of raw materials received from suppliers	E3	Supplier error	A3
	Raw material checking	The quality of raw materials decreases	E4	Raw material manufacturer error	A4
		There is a mismatch between the recorded and actual stock of raw materials in the warehouse	E5	Taking material is not according to SOP	A5
		There is 1 warehouse that lacks raw materials	E6	Plan & scheduling that has been made is not effective	A6
Make	Production process	Color error	E7	Color similarity in the storage basket	A7
		Production delay	E8	Delay in material from suppliers	A8
		Machine breakdown	E9	Less routine machine maintenance	A9
		Defective product	E10	Operator who is not careful	A10
Deliver	Product delivery to consumers	Moldy products during shipment	E11	Humid warehouse and shipping transportation	A11
Return	Return of defective products	The company pays fines due to defective products	E12	Customer asks for compensation to the company because of defective products	A12

Table A2.
Aggregate Risk Potentials (ARP)

Risk Agent	Code	Priority	ARP				Category
			Value	Cumul.	Percent	Cumul. Percent	
Supplier overload	A2	1	1392	1392	19%	19%	Priority
Delay in material from suppliers	A8	2	1032	2424	14%	34%	
Less routine machine maintenance	A9	3	775	3199	11%	44%	
Careless operators	A10	4	704	3903	10%	54%	
Humid warehouse and shipping transportation	A11	5	665	4568	9%	63%	
Material collection is not according to SOP	A5	6	630	5198	9%	72%	
Supplier error	A3	7	505	5703	7%	79%	
Plan & scheduling that has been made ineffective	A6	8	486	6189	7%	86%	
Customer requests that change sports shoe models	A1	9	300	6489	4%	90%	Non priority
Raw material manufacturer error	A4	10	276	6765	4%	94%	
Customer asks for compensation to the company because of defective products	A12	11	256	7021	4%	97%	
Color similarity in the storage basket	A7	12	204	7225	3%	100%	

Table A3.
House of Risk 2

Risk Agent	Mitigation Action (PAk)									ARP
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	
A2	9	3	0	0	0	0	0	0	1	1392
A8	9	9	0	0	0	0	0	0	0	1032
A9	0	0	9	9	9	0	0	0	0	775
A10	0	0	0	9	9	0	0	0	0	704
A11	1	0	1	0	0	9	9	0	0	665
A5	0	0	0	1	3	0	0	9	0	630
A3	3	9	0	0	0	0	0	0	1	505
A6	1	0	0	0	0	0	0	1	9	486
Tek	24482	18009	7640	13941	15201	5985	5985	6156	6271	
Dk	4	3	3	3	3	3	4	3	3	
ETD	6120,5	6003	2546,667	4647	5067	1995	1496,25	2052	2090,333	
Rank	1	2	5	4	3	8	9	7	6	

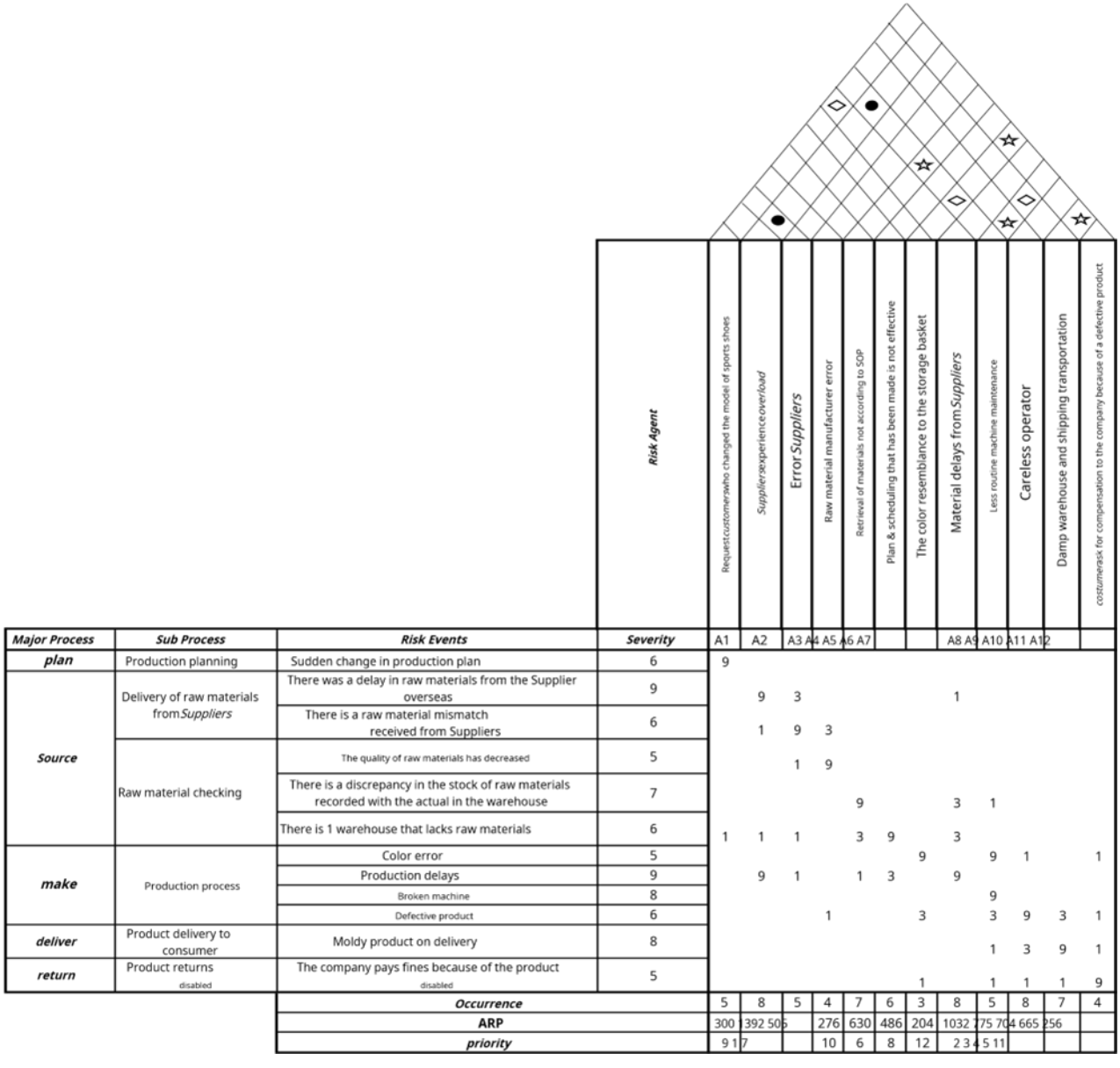

Figure B1. House of Risk (HOR) fase 1