FAILURE MANAGEMENT IN DISTRIBUTION LOGISTICS APPLYING FMEA APPROACH

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Abstract: *The negative effects of failures in logistics are recognized in literature and practice. In the last decade, more attention is paid to failure management in logistics systems. Failures in logistics processes have significant negative impact. As a results of failures logistics companies have additional costs, time losses, unsatisfied customers, marketing problems, etc. In this paper Failure mode and effects analysis (FMEA) approach is used for failure recovery in distribution logistics. For each of 36 identified processes severity, occurrence and detection are identified and risk priority number is calculated. In the observed example the most critical processes are transportation, goods control (quantity, quality, expiration date, damage) and goods extraction and putting on pallets. Corrective and preventive measures for failure reducing are also proposed in paper.*

Keywords*: distribution logistics, failures, FMEA*

1. INTRODUCTION

Customer service has been recognized as one of the most important goals of logistics systems. Customer service, in general, can improve customer relationships by three ways: (a) developing new services to be offered to the customer; (b) activating existing services or service element in a business relation c) turning the goods into a service element in the customer relationship (Gronroos, 1988). The importance of logistics service quality is recognized in literature and practice. Failures and customer complaints are one the most frequently used indicators of logistics service quality. Logistics service quality is equally important for logistics service providers and customers. Different methods and approaches are used in the literature for identification of failures in logistics and for measuring logistics service quality in general. Distribution is very important part of logistics. Failures in distribution are the most frequent and cause the customer complaints. Service recovery may be understood as a set of activities that a company performs to resolve complaints and to change the attitude of unsatisfied customers trying to keep them as loyal customers. One of the most important factors is how the complaint is handled. Logistics and distribution are very important in the execution of a business strategy, because directly create value to customers. Failure recovery is very important for customers. Thus, it is very important to plan, follow up and evaluate the failure recovery process (key customer services attribute) throughout the supply chain and not only in the final chain stage when there is a contact with the end consumer (Flores and Primo 2008). The role of logistics providers is very important in supply chain, because of the contact with at least two supply chain members and the making products available to customers. Thus, if customer service management must be seen as a supply chain process, failure recovery, as an integral customer

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service feature, must be seen in the same way (Flores and Primo 2008). The aim of this paper is to proposed new approach for failure recovery in distribution logistics. The next section describes FMEA approach in more details. The third section describes application of FMEA in distribution systems. Concluding remarks are given in the last section.

2. FAILURE MODE AND EFFECTS ANALYSIS (FMEA) APPROACH

FMEA is method, which was developed for the study of failures in different systems and processes. The procedure of this method is based on the failure characteristics and structure of observed systems and processes. For the purpose of the description of this method, is needed to define two basic terms:

Failure – ending the ability to perform the desired function object (the object after failure error, which can be partial or total). Failure is an event, error and condition (Šolc, 2012)

Fault – state of the object is characterized by its inability to perform a required function for reasons other than failure of preventive maintenance or other planned actions, or due to lack of external resources. In terms of product quality – failure is a condition where the product or service not meets customer requirements (Šolc, 2012).

The main objective of FMEA is to analyze potential defects/faults in the observed system and corrective measures that can reduce the risks. There are different benefits of failure detection: increasing the safety of functions and service reliability, reducing warranty and service costs, shortening the development process, better compliance of the planned terms, increasing process efficiency, increasing customer satisfaction, etc. FMEA discover and prioritize failures by computing risk priority number (RPN) which is a product of several risk factors: severity (S), occurrence (O) and detection (D). Severity describes the seriousness (effects) of the failure. Each effect is given a severity number from 1 (no danger) to 10 (critical). In this paper, we use severity ratings proposed in Chin et al. 2009 (Table 1).

Table 1: Traditional ratings for severity of a failure (Chin et al. 2009)

Rating	***Effect***	***Severity of effect***
10	Hazardous without warning	Very high severity ranking when a potential failure mode effects safe system operation without warning
9	Hazardous with warning	Very high severity ranking when a potential failure mode affects safe system operation with warning
8	Very high	System inoperable with destructive failure without compromising safety
7	High	System inoperable with equipment damage
6	Moderate	System inoperable with minor damage
5	Low	System inoperable without damage
4	Very low	System operable with significant degradation of performance
3	Minor	System operable with some degradation of performance
2	Very minor	System operable with minimal interference
1	None	No effect

Occurrence describes the probability of failure appearance. Ratings for failure probability proposed in Chin et al. 2009 are used in this paper (Table 2).

Table 2: Traditional ratings for occurrence (probability) of a failure (Chin et al. 2009)

Rating	*Probability of occurrence*	*Failure probability*
10	Very high: failure is almost inevitable	>1 in 2
9		1 in 3
8	High: repeated failures	1 in 8
7		1 in 20
6	Moderate: occasional failures	1 in 80
5		1 in 400
4		1 in 2000
3	Low: relatively few failures	1 in 15,000
2		1 in 150,000
1	Remote: failure is unlikely	<1 in 1,500,000

Detection can be defined as the ability to detect the failure before it reaches the customers. The assigned detection number measures the risk that the failure will escape detection. A high detection number indicates that the chances are high that the failure will escape detection, or in other words, that the chances of detection are low (Ambekar et al. 2013). Detection ratings used in this paper are shown in table 3.

Table 3: Traditional ratings for detection (Chin et al. 2009)

Rating	*Detection*	*Likelihood of detection by design control*
10	Absolute uncertainty	Design control cannot detect potential cause
9	Very remote	Very remote chance the design control will detect potential cause
8	Remote	Remote chance the design control will detect potential cause
7	Very low	Very low chance the design control will detect potential cause
6	Low	Low chance the design control will detect potential cause
5	Moderate	Moderate chance the design control will detect potential cause
4	Moderately high	Moderately high chance the design control will detect potential cause
3	High	High chance the design control will detect potential cause
2	Very high	Very high chance the design control will detect potential cause
1	Almost certain	Design control will detect potential cause

After these three basic steps, risk priority number (RPN) is calculated. After ranking the severity, occurrence and detectability, the RPN can be easily calculated by multiplying these three numbers: $RPN = S \times O \times D$. The failure modes with the highest RPN should have the highest priority for corrective actions.

3. APPLICATION OF FMEA IN DISTRIBUTION SYSTEMS

Distribution process analyzed is this paper is shown on figure 1. The first process is product ordering. The first aspect of product ordering is ordering from suppliers, while the second is customer ordering. All activities in this process relate to information flow. The next process is warehousing. Activities in this process may be divided in two segments. In the first segment, are activities of goods receiving and storage, while the second are activities of order processing and preparing for delivery. Warehousing largely depends on speed of information exchange. Order picking process is the crucial process in warehouses. The following is the process of packaging. Packaging process is realized through merging goods from different segments, forming transport units, goods inspection, as well as the loading goods in vehicles. Packaging is in direct relation with the order processing and distribution (transport). The transport is key processes in the product distribution process (Andrejić et al, 2016). This process largely affects customer satisfaction. The process that is related to all mentioned processes is inventory management. The last process is unloading goods in the retail stores (Andrejić et al, 2015).

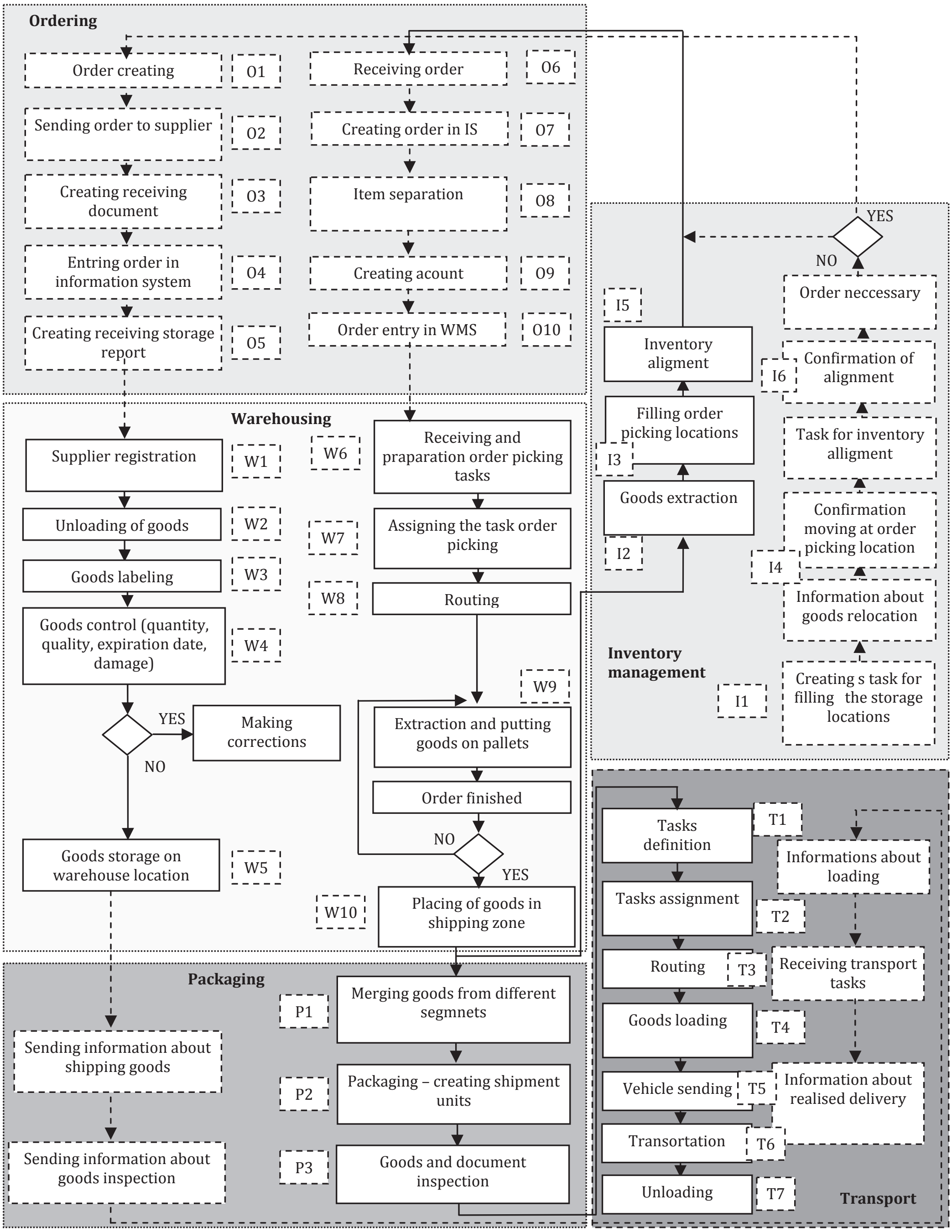

Figure 1. Distribution process decomposition (Adapted from Andrejić et al. 2015)

All activities in each process are marked as shown in figure 1. In observed example ten activities are identified in ordering process (O1-O10), ten in warehousing process (W1-W10), three in packaging process (P1-P3), six in inventory management process (I1-I3) and seven in transport process (T1-T7). For each activity, necessary parameters are calculated. As a result risk priority numbers are calculated for all 34 activities as shown in table 4.

According results the most critical is transportation process with the largest risk priority number. There are numerous potential risk and failures in transportation process. Transport failures greatly affect delivery process and customer complaints. There are different aspects of transport failures in literature. Delayed shipping is the most important and the most frequent. The potential reasons of this mistake are driver, congestion, wrong route calculation, etc. Damage of goods in transportation process is also important.

The next is goods control with the risk priority number 294. There are problems in the warehousing process when supplier supplies the goods of low quality and short expiration date. One of the basic steps is to define the level of quality and dimensions (specific checklists) of each unit of goods for each supplier. A relative small number of employers in this process limit the level of control. Putting away is very important activity in warehouse. A large number of mistakes are generated in this process. In real systems, order pickers realized this activity. Frequently relocation of order pickers from picking to putting away and control process greatly affects the occurrence of failures and reducing the level of customer service. They realize this process with insufficient attention. Assignment of smaller number of workers that will realize only putting away and control process should reduce failures to minimum. Inappropriate organization of space may affects failures. Managers in warehouse often have the goal of minimizing the space for order picking. One of the main aim is to reduce the effort in the order picking process. However, a large number of similar items at very short distances can cause failures (Andrejić et al. 2015).

Table 4. FMEA parameters calculation

Process	***R (Severity)***	***P (Probability)***	***N (Detection)***	***RxPxN (Risk Priority Number)***		***Process***	***R (Severity)***	***P (Probability)***	***N (Detection)***	***RxPxN (Risk Priority Number)***
O1	6	5	3	90		W10	4	3	3	36
O2	3	3	3	27		P1	8	5	5	200
O3	4	5	4	80		P2	3	4	3	36
O4	6	7	5	210		P3	6	5	5	150
O5	4	5	4	80		P4	2	3	4	24
O6	2	2	3	12		I1	3	4	4	48
O7	6	5	5	150		I2	6	6	5	180
O8	5	6	3	90		I3	4	3	4	48
O9	7	5	4	140		I4	4	4	4	64
O10	4	5	4	80		I5	7	6	5	210
W1	2	2	2	8		I6	4	5	4	80
W2	8	5	4	160		T1	6	5	5	150
W3	5	5	4	100		T2	4	3	4	48
W4	7	6	7	**294**		T3	7	6	5	210
W5	4	5	6	120		T4	7	7	4	196
W6	5	4	4	80		T5	4	3	3	36
W7	3	3	3	27		T6	8	7	7	**392**
W8	8	6	5	240		T7	7	7	4	196
W9	6	6	7	**252**						

The third process with the highest risk priority number is the goods extraction and putting on pallets. This part of order picking process is the most critical which confirms the value of risk priority number. There are different criteria for identification of failures in order – picking process. According place of identification there are internal (in house) and external (outside) failures. External failures in the most cases cause customer complaints. In the literature there are four basic categories of failures: typing failures (addition, confusion, etc.), failures in amount (shortage, excess, etc.), omission failures and condition failures (damage, lack of packaging, labeling). The failure rate depends of type of order picking system: pick-by-voice (0.08%), voucher (0.35%), labels (0.37%), pick-by-light (0.40%), mobile terminals (0.46%), mob. terminals + labels (0.94%). Order picking process is work and labor intensive process. Failures may be reduced if the order pickers strictly follow information system, and do not make decisions alone. Like in the process of order picking process the same situation is in the order processing, packaging and loading. It is very important to assign workers for particular processes. (Andrejić et al. 2013).

3. CONCLUSION

The importance of failure recovery in logistics is recognized in the literature and practice. There are numerous failures in distribution logistics. In this paper FMEA approach is used for failure identification and correction in distribution process. In observed example 36 processes are identified. For each process severity, occurrence and detection are identified, and in that basis risk priority numbers are calculated. According results the most critical processes are: transportation, goods control (quantity, quality, expiration date, damage) and goods extraction and putting on pallets. Proposed measure can reduce failures and improve distribution process. Future research should be dedicated to application FMEA, and other hybrid approaches in different logistics systems.

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