Vulnerability Analysis of Store-to-Store Delivery

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***Abstract*—**The issue of risk management in logistic has been noticed gradually and vulnerability is an important part in risk management. The main purpose of the research is to discuss failures and vulnerability of Store-to-Store delivery system. First, we developing service blueprint through in-depth interview with experts to find out failures in delivery process and its causes. Second, decision making trial and evaluation laboratory are used to find the relationships and intensity among failures, evaluating system's vulnerability. The results show that tally error, received by mistake and barcode label damage are the top 3 of failure situation. Improving POS system, goods examination process in store, clerk, and human assortment quality help the logistic system perform better.

***Keywords*—**Decision Making Trial and Evaluation Laboratory; E-commerce; Store-to-Store Delivery System; Vulnerability.

***Abbreviations*—**Decision Making Trial and Evaluation Laboratory (DEMATEL).

I. INTRODUCTION

ONLINE shopping is one of the most important applications of the Internet and logistics delivery is the most common type of service mistake in online shopping. Reducing the frequency of delivery mistakes will enable the building of a more complete online shopping mechanism. Convenience stores in Taiwan have in recent years extended B2C logistics services (Buy Online, Pick-up in Store) to include C2C delivery services through the Multimedia Kiosk (MMK). FamilyMart, for example, has integrated the MMK (Famiport) with its own logistics service to offer store-to-store delivery services. Consumers can use the Famiport in any FamilyMart store to specify the recipient's pickup details and once the goods have been delivered to another store they have specified, the recipient will receive a SMS notifying them to make the pick-up. Store-to-store deliveries can be used not only for e-commerce but also for non-commercial delivery needs.

As the external environment continues to change, the issue of risk management has gained increasing importance with logistics chain researchers [1]. The concept of vulnerability, in particular, has been extensively studied and explored in various fields. The concept of vulnerability refers to the impact on the system after a disaster occurs [3, 4]. A large impact indicates high vulnerability, and vice versa. Risk has three main components, these being Hazard, Exposure and Vulnerability. When Hazard and Vulnerability occur in the same time and space, Risk is created [2]. Research on vulnerability can be classified into three types [5]: The first type of research believes that vulnerability is related to pre-existing conditions so that the emphasis is on the sources of vulnerability, in other words, the potential exposure to disaster or risk. The second type of research believes that vulnerability and response to disaster are related so that the emphasis is on resistance to disaster and the ability to recover from a disaster. The third type of research is a combination of the two preceding types and looks at risk, resistance and recovery ability, and the points of vulnerability. Vulnerability is the ability of the individual or group to predict, handle, resist and recover from disaster [6, 7]. A full vulnerability assessment model should contain three basic elements: Exposure, Sensitivity and Adaptive Capacity. Here exposure refers to the risk of disaster while adaptive capacity is the ability to withstand the impact and continue operating as well as recover after the impact.

The concept of vulnerability has many applications in the supply chain: Juttner defined supply chain risk as the potential results of interference and changes in subjective value [8]. Svensson defines supply chain vulnerability as random acts of interference triggered by the internal and external risks of the supply chain that cause the supply chain to deviate from its normal operation and have an adverse impact [12]. Tang feels that if a business does not draw up a suitable risk management strategy for the supply chain then it will lose its competitive advantage [13]. Tang also believes that the supply chain vulnerability cannot be determined through direct observation. Inspecting the driving factors of vulnerability however will allow us to understand the causes of vulnerability in that system.

The FamilyMart convenience store in Taiwan integrated its MMK and internal logistics delivery mechanism to create a store-to-store service. Although this expanded the framework of its logistics service, the start and end points of this logistics delivery system are both convenience stores. The convenience store must therefore help with resolving any problems that arise during the delivery process so it differs on a fundamental level from the conventional logistics industry. If there should be a problem with deliveries between consumers, hidden delivery vulnerability factors such as responsibility and risk liability then become an important topic for managers [11, 14]. An understanding of vulnerability allows the manager to invest resources in the most vulnerable areas and optimize the allocation of limited resources.

This research studies the "Store-to-Store Delivery" service provided by the FamilyMart CVS and uses the Decision Making Trial and Evaluation Laboratory (DEMATEL) to analyze the factors that influence the vulnerability of the store-to-store delivery system, and the relationship between the factors. By helping the manager clarify the causes of vulnerability in this logistics system, a strategy for reducing logistics vulnerability can be proposed.

II. Store-to-Store Delivery System

The proliferation and 24-hour operation of convenience stores led to Taiwan developing the "Buy Online, Pick-Up In Store" delivery method allowing consumers to pay and pick-up their online purchases at a convenience store of their choosing. This particular delivery method has proven to be relatively successful in the B2C business model. As the auction market continued to grow and develop, convenience stores in Taiwan extended the "Buy Online, Pick-Up in Store" into the "Send and Pick-Up at Convenience Store" store-to-store delivery service. This satisfied not only the requirements of the C2C markets but also the ordinary buying and delivery requirements, as well, making it a delivery system to rival courier and postal deliveries.

FamilyMart was the first convenience store in Taiwan to offer the store-to-store delivery logistics service. Its store-to-store delivery service's target of "Send Today, Pick-Up at 6 am the Day After" has an accomplishment rate of around 96%. Using FamilyMart as an example, the workflow of the store-to-store delivery service (see Fig. 1.) is detailed below:

1. Send package at store: The sender packages the goods then uses the MMK at the convenience store to set and print the delivery details. The delivery form and package is then submitted at the counter. The store staff measures the package to make sure it falls within the given dimensions. After scanning the barcode and collecting the payment, the form is placed in a special bag and the package temporarily stored in a suitable location.
2. Collection: The logistics truck will travel to the convenience store between 10PM that night and 7AM of the following day to deliver goods and collect packages sent from that store. The store staff can use the POS to see how many packages are to be sent today and exit scan them one by one before handing them over to the driver to be taken back to the distribution center.
3. Sorting: Once the logistics truck returns to the distribution center the packages are scanned one by one, re-packaged with dedicated store-to-store delivery packaging and delivery labels, then sorted by the automatic sorting system.
4. Delivery: The driver delivers the package to the store and verifies the delivery with the store staff. The store staff uses the store's POS to scan the logistics barcodes on the package and then places it in a suitable location to wait for pick-up by the recipient.
5. Store Pick-up: The convenience store sends a SMS to the recipient. Once the recipient receives the SMS they must present their ID at the store and pick-up the package within 7 days.

FamilyMart's store-to-store delivery service currently processes around 100,000 packages each month. Common problems included sorting errors, damaged labels, incorrectly delivered package, and package damage. Fig. 2 is a problem analysis based on 2013 shipping statistics. In Fig. 2, it is possible to see that sorting error accounted for a very large proportion (51.4%) followed by label damage (30.5%) with incorrect delivery in third place (10.76%) and then product damage (5.83%). Most of the product damage were due to mistakes during delivery or sorting but were also occasionally due to sender mistakes. Although the proportion of system errors was extremely low (around 1.18%), when a problem happens it impacts on a very large number of packages. Other types of logistics problems include distribution center (0.35%), no delivery details (0.28%), loss or missed delivery (0.14%). The above analysis shows that delivery and sorting were the main sources of error and must accept most of the responsibility.

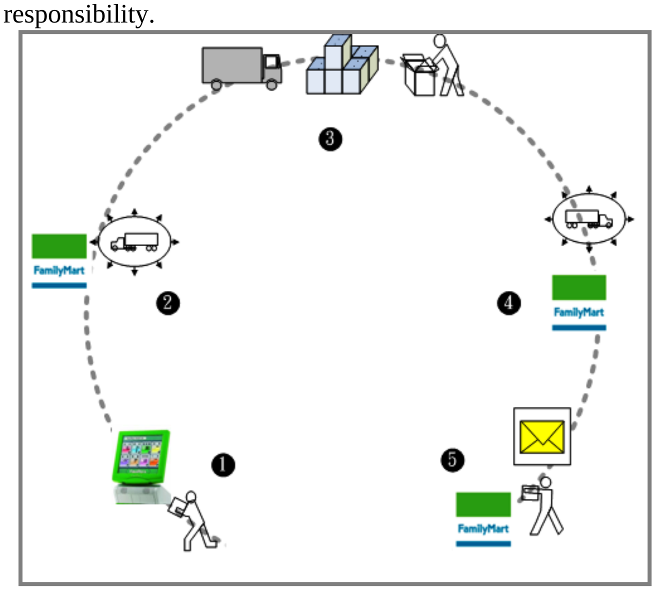

Figure 1: The Process of Store-to-Store Delivery System

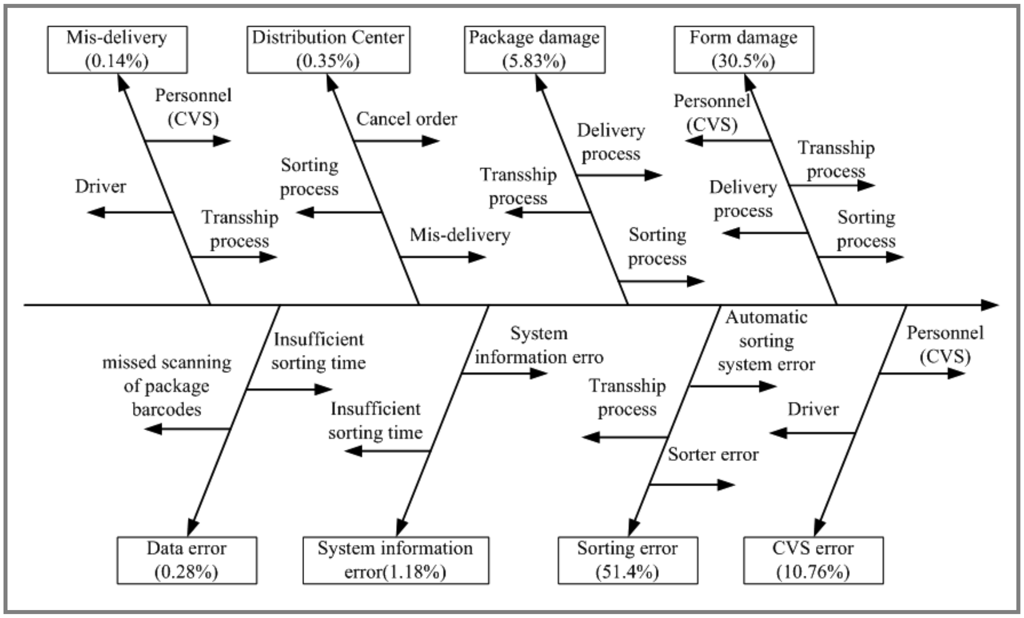

Figure 2: Fishbone Diagram of Store-to-Store Delivery Service

III. DATA AND ANALYSIS RESULTS

DEMATEL can help the manager analyze the correlation between system factors as well as the key factors and sub-factors that influence the system. The analytical results of DEMTAL can therefore give the manager an understanding of the complex relationships among system factors. DEMATEL consists of the following steps [9, 10]: (1) Define the system factors and the correlation between two factors. The relationship can be expressed as 1, 2, 3 or 4 to represent different levels of influence; (2) Calculate the initial direct influence matrix: Having an assessment factor will generate a $n \times n$ direct influence matrix. Each value z_{ij} in the matrix indicates the level of influence factor i has on factor j. Normalizing the influence matrix gives an intensity matrix X; (3) Derive the full direct/indirect influence matrix: when the intensity matrix X is known, use the equation (T = -1 X (I -X)) to determine the total influence matrix T; (4) the sum of every column and row in the total influence matrix T gives the sum D of each column and the sum R of each row. D indicates the degree to which a factor directly or indirectly influences another factor, while R indicates the degree to which a factor is influenced by another factor; (5) Calculate D+R (representing the strength of relationship between factors) and D-R (representing degree of influence on a factor). Using D+R as the x-axis, and D-R as the y-axis to draw a factor distribution graph allows the mutual influence between factors to be analyzed.

The store-to-store delivery system is very large and complex as it encompasses convenience stores, distribution centers, logistics information system, delivery fleet and the actual sender. The delivery system can therefore have many points of failure. This research compiles a list of more common problem factors through a number of expert interviews. The 23 problem factors are then sorted into the three categories of “Information”, “Personnel” and “Package” (see Table 1.).

The DEMATEL data came from the expert surveys. This paper chose the FamilyMart convenience store as the research subject and a total of 10 expert surveys were distributed to 2 project managers, 1 manager, 1 section chief, 1 assistant manager at distribution center, 1 logistics manager, 1 logistics section chief, 1 IT manager and 2 IT specialists. The experts answered the surveys using 1, 2, 3 or 4 based on their experience and perception of the relationship among the factors. Here 1 represents “Low level of correlation”, 2 represents “Average level of correlation”, 3 represents “High level of correlation” and 4 represents “Very high level of correlation”. The results of the DEMATEL calculations show that the factors with larger D values were in the descending order system information error, reporting (save) error, problem-related return, operator error at dispatching store, automatic sorting system error and operator error at pick-up store. The factors with higher R values were on file but there were no package, operator error at pick-up store, problem-related return, reporting (save) error, lost package, driver delivery error and operator error at dispatching store.

(D+R) represented the total influence of the factory on the system and how closely it was related to the system. The mean value was 2.91; (D-R) representing the degree to which a factor was influenced by other factors in the system. A cause and effect correlation graph was drawn using (D+R) as the horizontal axis and (D-R) as the vertical axis (see Fig. 3.). The four quadrants in Fig. 3 each have their own meaning. In the first quadrant, (D+R) is above average and (D-R) is greater than zero so these are the core problems in the system. They tend to be causes that influence other factors and should be corrected as a matter of priority. In the second quadrant, (D+R) is below average while (D-R) is greater than zero so these factors are highly independent within the system and affect only a few factors. In the third quadrant (D+R) is below average while (D-R) is less than zero so these factors are highly independent within the system and are only influenced by a few factors. In the fourth quadrant (D+R) is above average while (D-R) is less than zero so these are core problems within the system. The value of (D+R) indicates the link with the system. The higher this value is, the easier it is for the factor to have multiple impacts on the system. Fig. 3 showed that the factors with the highest (D+R) were in the order of X_2 (reporting → save error), X_{21} (problem-related return), X_3 (system information error), X_8 (operator error at pick-up store), X_{19} (on file but no package), and X_7 (operator error at dispatching store). These were therefore the more vulnerable factors in this system as defined in this research. The factors with higher values for (D-R) indicate key factors that offer the most gains for corrective action. The factors with higher (D-R) values were in the order of X_{15} (automatic sorting system error), X_3 (system information error), X_4 (POS system error), X_{16} improper package verification→ store-side), X_{14} (form error)and X_1 (inaccurate electronic map).

Table 1: Problem Factors

<table>
<tr><th colspan="2">Problem Factor</th><th>Index</th><th>Remarks</th></tr>
<tr><td rowspan="5">Information</td><td>Inaccurate electronic map</td><td>X_1</td><td>The location and operating status shown on the electronic map is not accurate</td></tr>
<tr><td>Reporting (Save) error</td><td>X_2</td><td>Information not uploaded to the database per normal procedure. This includes not entering details in time, information not sent and entered information not properly saved</td></tr>
<tr><td>System information error</td><td>X_3</td><td>The system did not display the correct information at a certain point in time. This includes information status error, data error and no data</td></tr>
<tr><td>POS system error</td><td>X_4</td><td>POS system experiences unexpected anomaly including information not sent or problem with information upload/download</td></tr>
<tr><td>Pick-up notification error</td><td>X_5</td><td>The systems send the pick-up message late or not at all</td></tr>
<tr><td rowspan="7">Personel</td><td>Technician error</td><td>X_6</td><td>Mistake by IT technician including operator error, accidental deletion and poor maintenance</td></tr>
<tr><td>Operator error at dispatching store</td><td>X_7</td><td>Mistake during the store-side collection process including mislabeling, improper storage of package, new staff being unfamiliar with the process and handing over the incorrect quantity to the deriver</td></tr>
<tr><td>Operator error at pick-up store</td><td>X_8</td><td>Mistakes during the store-side pick-up process include: not checking packages per regulations, not knowing where a package is stored, telling the recipient a package has not arrived even though it is already in the store, and not checking the recipient name properly</td></tr>
<tr><td>Insufficient sorting time</td><td>X_9</td><td>Original sorting time is reduced due to an increase in package volume, late arrival of delivery truck at distribution center or insufficient manpower or equipment</td></tr>
<tr><td>Sorter error</td><td>X_{10}</td><td>Mistakes by sorters at distribution center including packaging error, barcode mis-application, sorting error, moving error and boxing error</td></tr>
<tr><td>Driver delivery error</td><td>X_{11}</td><td>Mistakes by the driver during collection and delivery process including moving error and short delivery</td></tr>
<tr><td>Pick-up error</td><td>X_{12}</td><td>Store staff gives the wrong package to the recipient</td></tr>
<tr><td rowspan="11">Package</td><td>Form problem</td><td>X_{13}</td><td>Includes the form being lost, detached or damaged, or the barcode cannot be scanned</td></tr>
<tr><td>Form error</td><td>X_{14}</td><td>Package has the wrong form (Mailing details of package B mistakenly applied to package A)</td></tr>
<tr><td>Automatic sorting system error</td><td>X_{15}</td><td>Sorting error caused by problem with automatic sorting system</td></tr>
<tr><td>Improper package verification (Store-side)</td><td>X_{16}</td><td>The driver failed to follow the package verification procedure during the store-side package handover including picking up extra packages, missed packages, and missed scanning of package barcodes</td></tr>
<tr><td>Improper package verification (DC-side)</td><td>X_{17}</td><td>The distribution center failed to follow the procedure for package verification, inventory and inspection</td></tr>
<tr><td>Lost package</td><td>X_{18}</td><td>Package is lost</td></tr>
<tr><td>On file but no package</td><td>X_{19}</td><td>There are more entries in the information system than the actual packages</td></tr>
<tr><td>Mis-delivery</td><td>X_{20}</td><td>Package not delivered to the right location (e.g. wrong distribution center or wrong store)</td></tr>
<tr><td>Problem-related return</td><td>X_{21}</td><td>Returns not due to the 7-day pick-up deadline expiring but due to form problems, damage or no file</td></tr>
<tr><td>Package damage</td><td>X_{22}</td><td>Returns to the distribution center due to package damage, leakage, water damage, or broken packaging</td></tr>
<tr><td>Transfer due to store closure</td><td>X_{23}</td><td>Package transferred to nearby store after store closure but the recipient was not notified in time</td></tr>
</table>

In Fig. 4, the direct influence graph of X_2 (reporting → save error) was drawn as an example. Due to the complex correlation between factors, those with a correlation over 3.5 were drawn in bold while those with a correlation under 2.5 were drawn with a dotted line to emphasize the more important or the less important correlations. All of the others were indicated using a normal solid line.

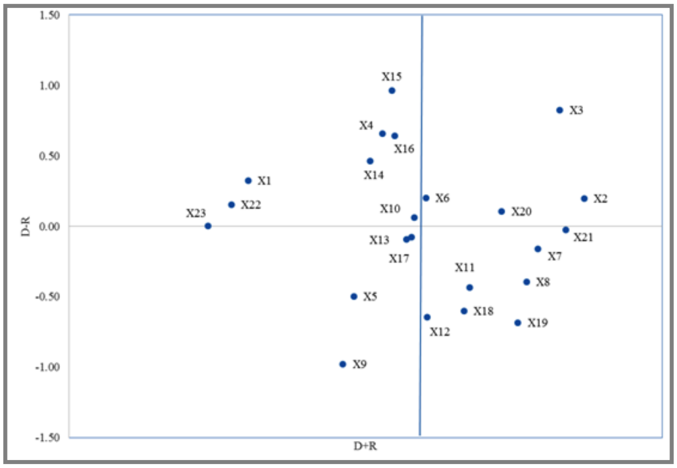

Figure 3: Effect Correlation Graph between D+R and D-R

From Fig. 4, it can be seen that X_2 (reporting → save error) is closely correlated to other factors and has an influence over most of them. All except for X_{10} (sorter error), X_{11} (driver delivery error), X_{16} (improper package verification→store-side), X_{18} (lost package), *and* X_{22} (package damage) were influenced by X_2. For X_4 (POS system error) in particular, the correlation was as high as 3.5, while X_1 (inaccurate electronic map), X_3 (system information error), X_5 (pick-up notification error), X_9 (insufficient sorting time), X_{17} (improper package verification→DC-side) and X_{20} (mis-delivery) all rated above 3 and many factors influenced X_2 (reporting→save error), as well. Apart from X_9 (insufficient sorting time), X_{10} (sorter error), X_{13} (form problem), X_{14} (form error), X_{22} (package damage) and X_{23} (transfer due to store closure), all of the remaining factors had an influence on X_2 (Reporting (Save) error) and X_6 (Technician error) in particular had a correlation as high as 3.67, while X_3 (System information error) and X_7 (Operator error at dispatching store)and X_8 (Operator error at pick-up store)all had a correlation of over 3.

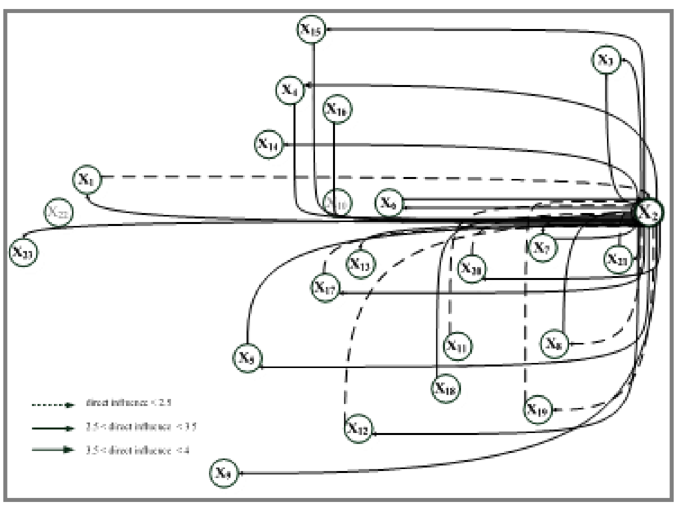
Figure 4: Direct Influence Graph

IV. Discussions and Implication

The results of the DEMATEL analysis show that IT and personnel were the key factors in the store-to-store delivery problems. On the IT system side, as the store-to-store delivery relies on the POS system for transmitting and processing logistics information, the POS system is therefore the most important window for exchanging data between the store-side and IT-side. It is therefore the most crucial core system. FamilyMart has over 2,800 stores throughout Taiwan and all of these stores rely on the data link between the POS system and the distribution center for their information. The POS system is not easy to introduce, manage and maintain however, so it should not only have suitable maintenance and troubleshooting procedures but also define a standard operating procedure (SOP) for handling POS problems that will help store staff deal with unexpected situations.

From the cause and effect correlation graph, personnel error can be seen to be the more vulnerable and difficult to manage part of the system. With sorters in distribution centers, for example, the detailed division of labor of sorting operations at the distribution center means the work is highly repetitive. The work may be easy but the sheer monotony can lead to distraction. At the same time, most sorters are part-time workers that have a high turnover rate so this tends to add to management complexity. In this case, give proper management and training to strengthen the sorters' familiarity with their work, cultivate good working habits and attitude among sorters, and train them to be alert to problems that will help to reduce the error rate among distribution center personnel.

As for store staff, logistics deliveries often arrive in the early morning during the graveyard shift. This is because convenience stores usually carry out their stock-in, re-stocking and store cleaning late at night. If a new employee on a graveyard shift is inadequately trained and unfamiliar with their work, this tends to lead to problems in the store-to-store delivery logistics. These may be packages not being properly handed over to the logistics driver, or the packages delivered by the logistics driver are not processed according to the SOPs. This then indirectly causes delivery delays or lost packages. For this reason, having an appropriate personnel management scheme and rigorously enforcing SOPs will help reduce the chances of personnel error.

V. Conclusion and Suggestion

The vulnerability of a company to interference can be determined by the possibility of damage and potential severity. When a company is assessing its vulnerability, it must try to understand the three following points first: (1) Why was there a mistake? (2) What are its odds of happening again? (3) What is the outcome, if it does happen? Reducing vulnerability means reducing the chances of interference and increasing recovery ability. This paper used DEMATEL to explore the issue of vulnerability of a store-to-store delivery system in Taiwan. The research findings show that reporting error and system information error were the most vulnerable elements in the delivery system, demonstrating the importance of the logistics IT system. Based on the results of the DEMATEL analysis, we suggest the following to management: (1) Ensuring the accuracy of reporting and the normal operations of the automatic sorting system are the most fundamental conditions for the normal operations of the store-to-store delivery system; (2) Improving the POS system and store-side verification process as well as the quality of store personnel and manual sorting will help to optimize the system. These factors are very beneficial for common mistakes such as sorting error, mis-delivery and label damage; (3) Inaccurate electronic map, package damage and transfer after store closure are highly independent factors that do not require a special investment to correct. Taking more care during routine operations and monitoring these issues separately in order to avoid mistakes will suffice.

Even though DEMATEL can effectively identify the key factors, factors that do not stand out in terms of cause or centricity on the correlation graph are not necessarily unimportant and should not be ignored. At the same time, although this research looked at "correlation", a higher correlation does not mean it actually happens more often. A judgment based on correlation is also more subjective. Focusing exclusively on correlation may lead to over-emphasis on events that do not happen very often and lead to analytical bias. Management resources may then be wasted on non-critical issues. The "possibility" in actual practice or the concept of RPN (Risk Priority Number) should therefore be incorporated based on real-world figures then considered along with their severity, incidence and detection possibility to correct any potential bias.

Acknowledgements

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