A Framework of Warranty Risk Management

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Abstract—**Warranty is a useful tool for a manufacturer to reflect its product quality and combat competition. It, however, introduces various risks that may have a direct impact on the profitability and reputation of the manufacturer. Although managing such risks is crucial in reducing the number of warranty incidents and warranty related cost, little research has systematically investigated warranty risk management (WaRM). As such, this paper aims to (1) analyse the existing literature on warranty-related risks; (2) develop a generic WaRM framework; (3) investigate the existing WaRM techniques and methods by surveying the warranty decision makers in the automotive industry in the UK, and then (4) propose a warranty hazard identification tool through utilising social media data.**

Keywords–warranty risk management; social media; automotive industry

I. INTRODUCTION

Nowadays, manufacturers may offer a competitive warranty policy to their customers to maintain or increase their market shares. However, offering warranty may introduce various risks that can have a significant impact on the manufacturer's profit and reputation. For instance, General Motors (GM) spent $2billion to recall 13.1 million vehicles in 2014 due to its ignition switch issue, which may cause safety problems for drivers and passengers.

In the literature, WaRM is not often discussed and only mentioned as a side topic in some papers. For example, [1] investigates the problem of efficiency in warranty programme. [2] adapts a method, or a Quality Function Deployment (QFD) method, to prioritise warranty-related activities that may affect customers' satisfaction. [3] proposes a warranty management framework that outlines the main issues in achieving the goal of a warranty programme and meet customers' satisfaction. [4] identifies the top contributors to warranty incidents and costs and then proposes a warranty hazard taxonomy.

This research therefore seeks answers to the following questions: How should a manufacturer plan its WaRM? What tools should be used to identify warranty hazards, assess warranty risks, and mitigate warranty risks, respectively? Accordingly, the novelty of this research includes: (1) It is the first research paper that systematically analyses WaRM and develops a generic WaRM framework; and (2) it is the first research paper that applies social media data to identify warranty hazards.

In this paper, Section II discusses WaRM tools; Section III designs a questionnaire and analysis it. Section IV develops a WaRM framework; Section V identifies warranty hazards from social media data; and Section VI concludes the paper.

II. WARRANTY RISK MANAGEMENT TOOLS

Risk is defined as "the effect of uncertainty on objectives" [5]. The effect can be a positive or negative deviation from what was planned. [5] defines risk management as a set of activities and methods employed to direct and control an organisation risks that can affect the ability to achieve its objectives. These activities have five stages: (1) risk planning; (2) hazards identification; (3) risk assessment; (4) risk evaluation, and (5) risk controlling and monitoring. Analogously, the definition of risk management, or Warranty Risk Management (WaRM), can be defined as the process that identifies and assesses warranty hazards, and then manages the associated risks that occur during warranty period, as elaborated below.

Warranty risk planning involves assigning roles and liabilities in order to avoid contrary decisions in respect of emerging risks and allocating the necessary budget, efforts and resources. Additionally, aligning the procedures of the managerial works (e.g., reporting and passing risk-related information to the interested departments) is necessary in developing a warranty risk plan. Techniques such as project network diagrams [6], precedence diagram method [7] and generalised activity networks [8] can be adapted. As the risk management programme is a continuous process during the warranty programme, warranty cost analysis needs reviewing periodically. The thresholds that determine the level of an acceptable risk is significantly important as it will be used as a reference point.

Warranty hazard identification answers the question of what could go wrong during the warranty period. To answer this question, an in-depth analysis of the product, during the pre-launched and post-launched stages, is required. To this end, general tools such as SWOT (Strength, Weakness, Opportunities and Threats) analysis and the analogy approach can be adapted to obtain a board view of potential warranty hazard. To obtain a detailed identification, one may use tools, such as Failure Mode and Effect Analysis (FMEA), interviewing experts, assumption analysis, documents reviews, Delphi technique, and brainstorming, among others. The identification of warranty hazards is a challenge due to its interacts with other departments, such as design, manufacturing, marketing, logistics departments. Data collected from those departments are important in identifying warranty hazards in addition to warranty data which is collected from the warranty service providers [9]. With the development of data warehousing and Big Data techniques, it is possible to collect a huge amount of data from different sources. Warranty-related data can also be collected from structured datasets (e.g., CRM, ERP, etc.)

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or unstructured datasets (e.g., social networks, specialized forums, blogs, etc.). Analysing both types through the Big Data analytics tools can provide useful information that is difficult to acquire with traditional tools of data analysis. The application of such techniques may detect warranty hazards at the early stage of the product lifecycle.

Warranty risk assessment may be based on qualitative or/and quantitative analysis. Qualitative analysis may aim to look for repetitive events and then decide any required actions, whereas quantitative analysis aims to assess the probabilities and consequences of warranty risk. The probability of warranty risk is the likelihood of occurrence of a hazard during the warranty period, and the consequences is the expected loss of the hazard, which can be determined by experts or by the comparison with similar events occurred in the past. In order to quantitatively measure warranty risk, one may use methods, such as sensitivity analysis, FMEA and Failure Mode Effect and Criticality Analysis (FMECA), fault tree analysis and event tree analysis [10], and sensitivity analysis variable [11].

Warranty risk evaluation is concerned with the ranking of warranty risks. Such risks are evaluated to determine the magnitude of each risk based on its impact severity and likelihood. The impact may have different criteria, such as warranty cost, manufacturers' reputation, human safety and environmental damage. To this end, methods such as decision tree analysis [11], portfolio management [12] and Multi-Criteria Decision-Making methods (MCDM), may be applied.

Warranty risk mitigation is concerned with the application of pre-specified mitigation plans in response to emerged warranty risks. Such plans aims to avoid the occurrence of risk, mitigate the impact of risk, transfer risk or retain risk. Some factors are essential to be considered to opt the appropriate plan: for example, (1) the severity of a consequence, (2) cost needed to deal with the risk, (3) required time, (4) warranty programme context, and (5) the impact of a consequence.

Warranty risk monitoring and review is essential in controlling the identified warranty risks. Consequently, such risks are periodically evaluated to understand whether or not they are within the controlled regions or need further actions.

III. Questionnaire analysis

In order to better understand WaRM tools used in practice, we surveyed warranty decision makers. A questionnaire, including 9 questions, was designed and then distributed to organisations of three types: suppliers, OEMs and dealers, in the automotive industry in the UK. These questions include two main sections, (1) respondents and their organisations' information, and (2) the existing WaRM tools used in their firms. Out of 70 questionnaires that were distributed by Qualtrics (https://www.qualtrics.com), 40 respondents were collected. The survey results are analysed in this section.

A. Organisations and the Respondents' Information

This subsection tries to understand the firms and the experience of the respondents.

Figure 1 shows the revenue distribution of the organisations that the respondents were working for: Most (i.e., 32%) of the respondents were from firms with revenue less than $100 million. Figure 2 shows their current management levels: the majority (60%) of respondents are in the middle-level management. Their experiences are grouped into four categories, and the large portion (51%) is the group of over-10-years' experience (see Figure 3). It is important in this research to survey those people who have a long period of experience as the hazard identification process relies heavily on the decision makers' experiences.

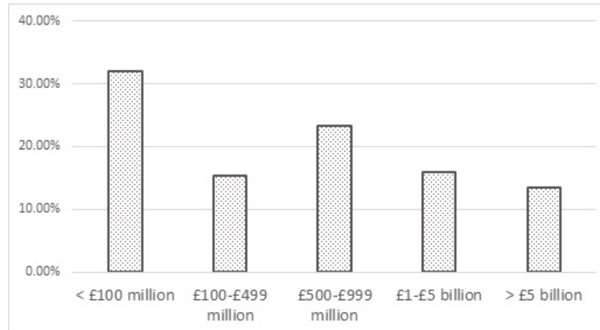

Figure 1. Organisations sizes.

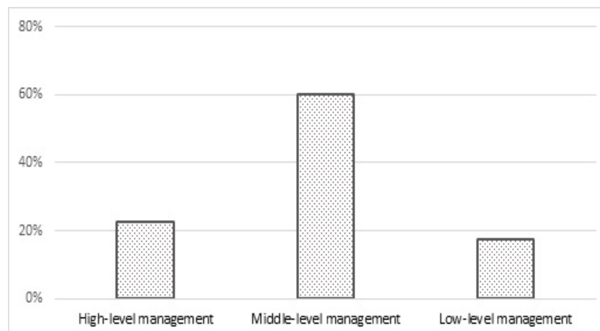

Figure 2. The management level of respondent.

B. Tools for hazard identification and risk assessment

To gain a better understanding of the existing WaRM in the automotive industry in the UK, this subsection aims to survey tools used in identifying warranty hazards and assessing their associated risks. Hence, the respondents were asked "Which tools are used by your organisation to identify warranty hazards?" Figure 4 shows that the most common tool (16%) used by their organisations is the root cause analysis technique, followed by both techniques, checklist analysis (15%) and information gathering (15%), respectively. The effectiveness of such tools in identifying warranty hazards relies on the accessibility to the required data at the proper time. For example, root cause analysis requires time to identify product failure causes and find the solutions accordingly 04 March 2019. Such a technique requires detailed information from the warranty services provider (dealer in this research) about product failures (e.g., failure symptoms, usage status, etc.). Unfortunately, collaboration among the organisations of the three types are often insufficient. Additionally, it takes time for the OEMs to aggregate the required information and then pass it to other parties (e.g., suppliers).

With regard to warranty risk assessment, the respondents were asked about the existing tool(s) used to assess warranty risk.

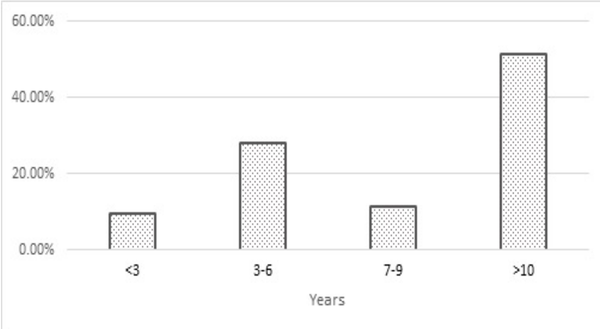

Figure 3. The respondents' experiences.

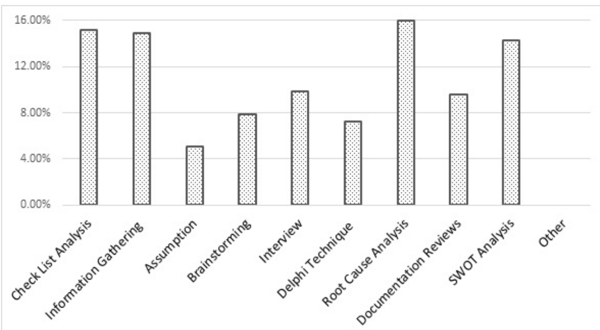

Figure 4. The existing hazards identification tools.

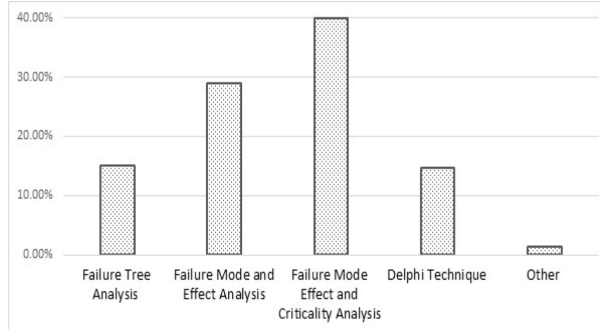

Figure 5. Warranty risk assessment tools.

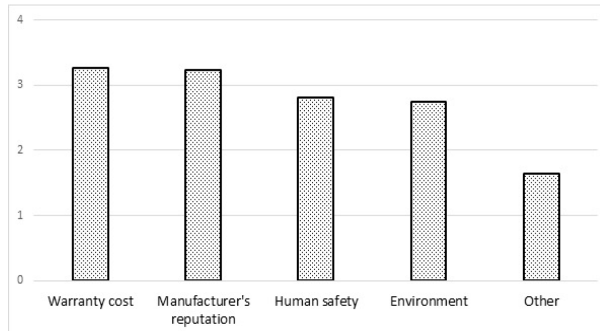

Figure 6. Criteria influenced by warranty risk.

Figure 5 shows that the most common (40%) technique used to assess warranty risk is FMECA, followed by FMEA (29%). The respondents were also asked "What are the limitations of the existing tool(s) used to assess warranty risk?" in order to determine the weaknesses. They listed different limitations, and mainly focused on the importance of updating the existing tools by taking the advanced technology into consideration. Additionally, the time issue required to process and access such tools is a challenge, these tools are unable to detect warranty hazards at the early stage of the product's lifecycle. For example, some of their answers regarding the limitations of such tools are: "Require human interaction" and "risks tend not to be known until an incident has happened on a recurring basis, and the tools do not always identify this as a risk". These responses imply that such tools need to be improved to identify hazards systematically, though some said: "there are no limitations".

Once a warranty incident has occurred, its impacts can be analysed based on different criteria. Therefore, the respondents were requested to answer this question "Once a warranty incident has occurred, what are the top criteria that can be severely influenced?" and they were asked to choose the impact severity level from "None" to "Catastrophic" for each criterion. From Figure 6, it can be seen that warranty risks have a medium to a severe impact on warranty costs and the manufacturer's reputation. On the other hand, the impact of such risks on human safety and environment ranges from minor to medium. The respondents were also asked about their warranty risk mitigation plans. Generally, they use different techniques, which can be grouped into (1) mitigation plans, such as recall, insurance, manufacturer support, and problem diagnosis; (2) software, such as CRM (customer relationship management); and (3) methods, such as Delphi, historical data collection and experience.

IV. A WaRM Framework

The ISO 31000 risk management framework [13] can be adopted in the development of a WaRM framework. As a result, a WaRM framework, as shown in Figure 7, is developed and interpreted in the following.

1) Determining the internal and external stakeholders who should be communicated or consulted with to gain inputs for each step of the framework. The engineering, marketing, finance, legal and accounting departments are examples of internal stakeholders, whereas suppliers, dealers, and distributors are examples of external stakeholders who may affect the decision of managing warranty risk. The communication and consultation is a continuous process through all the WaRM steps. It is important to understand the objectives of the stakeholders. Accordingly, such objectives can then be considered in setting a warranty risk plan.
2) Setting a warranty risk plan by determining warranty programme objectives and the factors that influence the achievement of such objectives. It is also important to determine the mitigation plans for each potential hazard by consulting experts or learning from the similar cases occurred at competitors.
3) Collecting hazard-related data from different sources. This step is the cornerstone in this framework as the warranty programme involves a high level of uncertainty, due to the complexity of products and the long warranty period, which makes it difficult to be planned at the previous

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steps. Additionally, since warranty management relates many parts of the manufacturer, identification of warranty hazards becomes more challenging. As such, this step is divided into four phases.

- *Data collection*: Data should be collected from all stakeholders, including the internal and external stakeholders. Due to difficulties in obtaining real-time data from these stakeholders, other sources of data such as customers' comments posted on the social media can be a good source. Combining information of both sources can improve the efficiency of the process of warranty hazard identification.
- *Data cleansing*: The collected data may include noisy data that are incompatible with the manufacturer database system, so one needs to pre-process and cleanse the data for further processing.
- *Data analysis*: The acquired information needs analysing to identify warranty hazards.
- *Classification*: The classification of the identified hazards is then used to facilitate the rest steps of WaRM. For example, the hazards can be broadly classified warranty hazard design related, manufacturing related, warranty-servicing related, customers related or information related hazards.

4) Assessing warranty risk associated with the identified hazards based on their likelihood (frequency rate) and their consequences severity of the risks based on some criteria. At this stage, the identified hazards will be assessed to find the associated risks. As such, the probability of each hazard will be assessed according to its frequency. Then, its impact on different criteria will be assessed based on the decision makers' experiences. Some tools can be adapted such FMECA, FMEA and others. Based on the result of questionnaire data analysis, it is found that the most common tools used to assess warranty risk is FMECA.
5) Evaluating the risks, which includes prioritising and ranking the risks based on their severity in terms of the given criteria. The warranty decision makers can then evaluate the risks and decide the acceptable and unacceptable ones. MCDM methods may be adapted to identify the local priority of such risks and the overall priority, which is used to determine and rank the risk among others. The analytic hierarchy process (AHP), for example, is one of the most commonly used MCDM tools and its application is vast in risk assessment and evaluation.
6) Mitigating the risks based on the outcomes of the above Steps 3) & 4) and based on the mitigation plans set in Step 2). Once the probability and impact of each risk are determined, they can be visualised. There are some tools can be used to perform this task, such as the risk matrix. It is important to monitor warranty risk on a real-time basis in order to detect failures at the early stage of products' lifecycle.
7) Visualising risks to gain a better understanding of the monitoring process and the warranty risk plan. The monitoring and review step is a continuous process with the all WaRM steps. For example, a warranty risk plan including procedures liabilities documentation and others need updating in response to the new changes. Likewise, the approaches used to identify, assess, evaluate and mitigate warranty risk should be updated, if necessary, according to such changes.

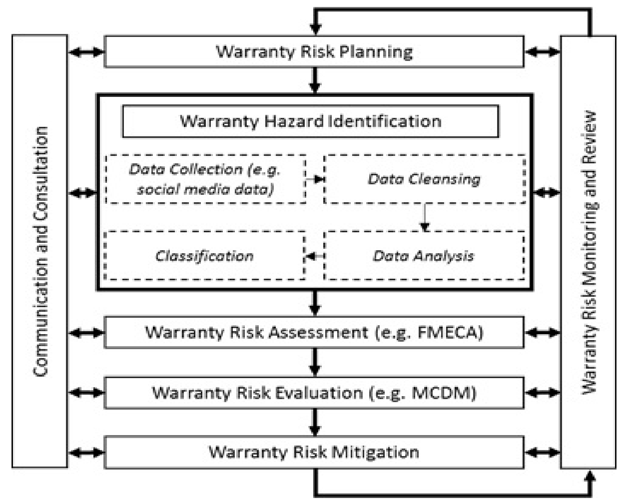

Figure 7. WaRM framework.

V. IDENTIFYING HAZARDS FROM SOCIAL MEDIA

Nowadays, a huge volume of information has been generated over the Internet. Many people share their unique interests and opinions through different platforms on the Internet, such as Twitter, Facebook, Instagram, YouTube, among others. Such information can reflect their experiences or complaints towards products, services and so forth. Therefore, such information is highly important and useful to different stakeholders, including manufacturers or warranty services providers. As such, analysing those data can provide useful insights and aids in developing products and improving organisations' strategies.

Conventionally, manufacturers rely on warranty data to analyse the abnormal events and then make decisions accordingly. This process, however, may take a long period (up to 2 months [14], say), which may lead to undesired consequences. As such, social media data can be used to obtain real-time information about product performance, which can help in detecting warranty hazards (e.g., product failure, service quality, etc.) at the early stage of product's lifecycle. Here, in the following, Twitter data will be used as an example of an early warning tool to identify warranty hazards. Twitter is a micro-blogging service which allows users to publicly and promptly write a tweet.

A. Illustration of the WaRM Framework

In this section, the proposed WaRM is validated through Twitter data following the process mentioned above.

Warranty risk planning, there exist several methods such as project network diagrams, design structure matrices (DSM) and others can be adapted to set a warranty risk plan. Warranty hazard identification is processed through four phases:

1) identifying the source of data and collecting data;
2) cleansing and analysing the collected datasets to obtain useful information in relation to warranty hazards;
3) analysing the cleansed data to find the characteristics of hazards;

4) classifying warranty hazards into design-related, manufacturing-related, logistics-related, warranty-servicing-related, customer-related and information-related hazards.

To apply the phases mentioned above, we collect data in relation to Ford Fiesta issues from Twitter. Ford Fiesta is one of the most commonly used cars that were sold globally in 2016. Some of its users complained product failures on Twitter. As mentioned before, while the proposed framework should be validated on the basis of real-world data/cases, more than 100 thousand tweets have been collected from Twitter based on some keywords. These keywords were determined based on analysing 300 comments posted by customers on different forums indicating vehicles' issues. After analysing such comments, the common keywords are failure, fault, fail, failed, break down, breakdown, service, warranty and problem among others. The collected tweets was then cleansed, including replacing blank spaces, removing punctuations, removing links, removing tabs and removing blank spaces.

It is also important to point out that there are duplicated data in the collected dataset, which results from the retweets, made by different users, and which are not deemed as duplicated tweets. As such, during the process of cleansing, they were kept as the main part of this dataset because they may reflect the concerns of other twitterers. As a result of the data pre-processing stage, around 44 thousand tweets are kept, from which tweets 23 thousand tweets are related to the research question.

Although this dataset gives information about the different warranty hazards relating to Ford Fiesta 2016, we list the four most frequently complained hazards in the following.

1) Transmission failure: The word frequency indicating this issue is 7129, which forms the highest complaint about the Ford Fiesta 2016. Customers have commented on this issue in many tweets, for example, "I experienced a problem with transmission Ford Fiesta 2016, it is lurching". In this dataset, alternative terms were used to describe this issue. For example, some tweeters have used "gearbox" where others used "gear" instead.
2) Acceleration failure: This is the second most complained issue in Ford Fiesta 2016. They complained, for example, that "♯Ford Fiesta 16, I faced the problem of acceleration twice last week, it was slow". The term "acceleration" has appeared in this dataset for 3627 times, which may need the interventions from the manufacturer.
3) Intermission failure: Some customers also complained about this issue during the taking off. They claimed that in their tweets "♯Ford Fiesta 2016 performance is not as we expected, there is an intermittent shudder when taking off". The intermittent term has been mentioned for 2941 times, all of which indicate this problem.
4) Rear door failure: Also, some customers have complained that the rear door might have a safety problem. They claimed that "Rear door of ♯Ford Fiesta may cause a higher risk of injury". As this term "rear door" has been mentioned 2850 times in this dataset, it needs paying attention.

It is important to note that there are other potential warranty hazards in this dataset but they showed less importance based on the words frequency. In order to assess the risks associated with the identified warranty hazards, the probability of each hazard will be multiplied with the expected consequences on the relevant overall of the four mentioned criteria (warranty cost, time, customer's satisfaction and firm's reputation), respectively. Consequently, those risks can be prioritised and ranked.

The severity of the risk in the identified warranty hazards varies from one manufacturer to another. Additionally, in terms of the aforementioned criteria, they may be different as well. Therefore, it is difficult to estimate the impact of such consequences unless domain experts in one firm are consulted in order to obtain their opinions regarding the impact of each hazard on each criterion.

To sum up, through the analysis of the dataset, a number of the identified warranty hazards have been observed. Mainly, customers complained about Transmission, Acceleration, Intermission and Rear Door. The frequency of such problems was 7929, 3627, 2941 and 2850, respectively, as shown in Table I.

TABLE I. THE PROBABILITY OF THE RISK ASSOCIATED WITH WARRANTY HAZARD

	Values	*Probability*
Transmission	7929	46%
Acceleration	3627	21%
Intermission	2941	17%
Rear door	2850	16%
Sum	17347	100%

From Table I, it can be seen that the four identified risks are related to the manufacturing risks which often raise warranty costs and lead to customers' dissatisfaction. Among the four hazards, the transmission in Ford Fiesta 2016 accounts for 46%. As a result, such a risk requires immediate intervention by providing the required spare parts, scheduling of maintenance and allocating the required fund and efforts, for example. The rest of the identified hazards should also be carefully checked although their probabilities are not so large as that of the transmission. That is, they should be controlled to ensure that the risks are under their acceptable levels.

In order to prioritise and rank the identified warranty risk, some tools may be used to visualise the magnitude of the identified risk, such as word cloud and link graph, as shown in Figures 8 and 9, for example.

Figure 8. Word cloud for the Ford Fiesta 2016 related Twitter data.

Figure 9. Link graph for the Ford Fiesta 2016 related Twitter data.

VI. Conclusions

Managing warranty risk is crucial to protect manufacturers from a huge warranty cost. This paper has analysed the literature and surveyed some decision makers in the automotive industry in the UK to obtain an in-depth understanding of the WaRM in practice. A generic WaRM framework was then developed.

The main findings are that the root cause analysis is the most widely used tool in identifying warranty hazards, and the FMECA technique is the most commonly used tool for assessing warranty risk in the automotive industry in the UK. In addition, warranty cost and the manufacturer's reputation are the most susceptible criteria to warranty risk.

To demonstrate the utility of social media data in identifying warranty hazard, we collected and then analysed Twitter data as an example of a real-time warranty identification tool and analysed the collected data.

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