Advancing Pavement Surface Evaluation to Support Engineering and Investment Decisions

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ABSTRACT
The American Association of State Highway and Transportation Officials (AASHTO's) Pavement Rutting and Cracking Quantification Expert Task Group (ETG) was formed in 2006 with Federal Highway Administration (FHWA) funding to provide program guidance and assistance in development and enhancement of standards for pavement rutting and asphalt pavement surface cracking. The ETG was formed with subject matter experts to represent AASHTO, FHWA, the American Society for Testing and Materials (ASTM) Committee E-17 on Vehicle-Pavement Systems, Transportation Research Board (TRB), the Long Term Pavement Performance (LTPP) Program, academia, and industry. Revised data collection and analysis protocols have been produced and evaluations are being initiated to identify how best to continue the development process.

INTRODUCTION
The collection of quality pavement surface evaluation data is critical for pavement management and design. The current national and State efforts to develop and refine pavement performance measures have revitalized the need for being able to collect quality performance data consistently and cost effectively.

The implementation of new project delivery methods, with medium to long-term maintenance agreements (Design Build Maintain, Design Build Operate, etc.) are similarly re-emphasizing this need for performance measures to direct maintenance and rehabilitation strategies. Again, a high level of quality data is needed for proper planning and optimal funding allocation.

The implementation of the Mechanistic Empirical Pavement Design Guide (MEPDG) also highlights the need for quality pavement evaluations to maximize the potential of the MEPDG. The effectiveness of any pavement design models are of course a function of the pavement performance data used to develop and calibrate them.

The emphasis on pavement preservation has also highlighted the need for more reliable measures of pavement performance. In working to optimize limited resources for maintaining serviceable pavements, one of (if not the) most critical factors is timing of treatment applications. Timing is based on data collected to define how a pavement is performing at a given point in time.

All of these current focal points in the pavement field clearly identify the need for high quality pavement evaluation data. Current Transportation Legislation has underscored this need by requiring consistent and reliable measures of performance on which funding needs can be quantified.

BACKGROUND
Pavement evaluation has been developing for decades. AASHTO has published pavement condition standards for both rutting and cracking that are utilized by pavement analysts. AASHTO standard R 48-10 uses a minimum of five transverse profile points to determine rut depth (*1*). Crack quantification for asphalt pavement surfaces is detailed in AASHTO standard R 55-10 (*2*). ASTM defines a Pavement Condition Index (PCI) as a numerical representation of a pavement surface condition (*3*). The PCI can be evaluated and monitored over time to determine and prioritize maintenance and rehabilitation needs. ASTM standard D6433-11 is the current publication describing the PCI method and use.

The FHWA Distress Identification Manual is another widely accepted guide for conducting manual distress surveys (*4*). Many state agencies and other entities use the manual to ensure uniform survey results across different regions.

Most of these procedures are based on manual distress surveys or other similar dated procedures. With increasing technology, the interest in automating these pavement evaluation procedures continues to evolve. There are numerous studies comparing automated pavement surveys to manual survey methods. Overall, automated methods prove to be less time-consuming, more accurate, safer and less expensive. A paper published in 2002 by TRB, provides an example of a study which explores the data analysis capabilities of an automated pavement survey system (*5*). The paper discusses the real time processing of survey data using digital technology. The study concludes that distress survey results of the same section of pavement are repeatable using the automated survey system.

A similar study described the network survey of the Arkansas State Highway and Transportation Department's non-interstate National Highway System (NHS) in a 2003 TRB publication (*6*). The survey team utilized the Digital Highway Data Vehicle and automated Distress Analyzer to survey approximately 100 miles of pavements. Conclusions of the survey included effectiveness in speed and accuracy over manual methods. They also concluded that there are potential costs savings associated with automated distress surveys over older manual surveys (*6*).

Building on studies of evolving technology, agencies started looking to adopt these technologies for their pavement evaluation practices. As these early adopters quickly learned, there was little standardization or guidance on which to implement these new technologies. The AASHTO Subcommittee on Materials, Technical Section 5A, (Pavement Measurement Technologies) also recognized the need to gather an ETG to update the existing AASHTO standards. This AASHTO ETG was assembled in 2006 (FHWA funding) to provide program guidance and assistance in development and enhancement of standards for pavement rutting and asphalt pavement surface cracking.

The group consisted of subject matter experts to represent AASHTO, FHWA, the ASTM Committee E-17 on Vehicle-Pavement Systems, TRB, LTPP, academia, and industry. An Annual Public Works Association (APWA) Reporter article describes the development of new crack and rutting standards that encompass new automated collection and analyses systems (*7*).

PAVEMENT SURFACE EVALUATION STANDARDS

Existing AASHTO rutting (R 48) and cracking (R 55) standards are expected to remain valid and used by some organizations. The rutting standard (R 48) was designed for determining rut depth based on five points across the pavement (see FIGURE 1 below). However, current technology allows for significantly more transverse points. These additional points allow a more complete analysis of rutting and edge drop-off parameters.

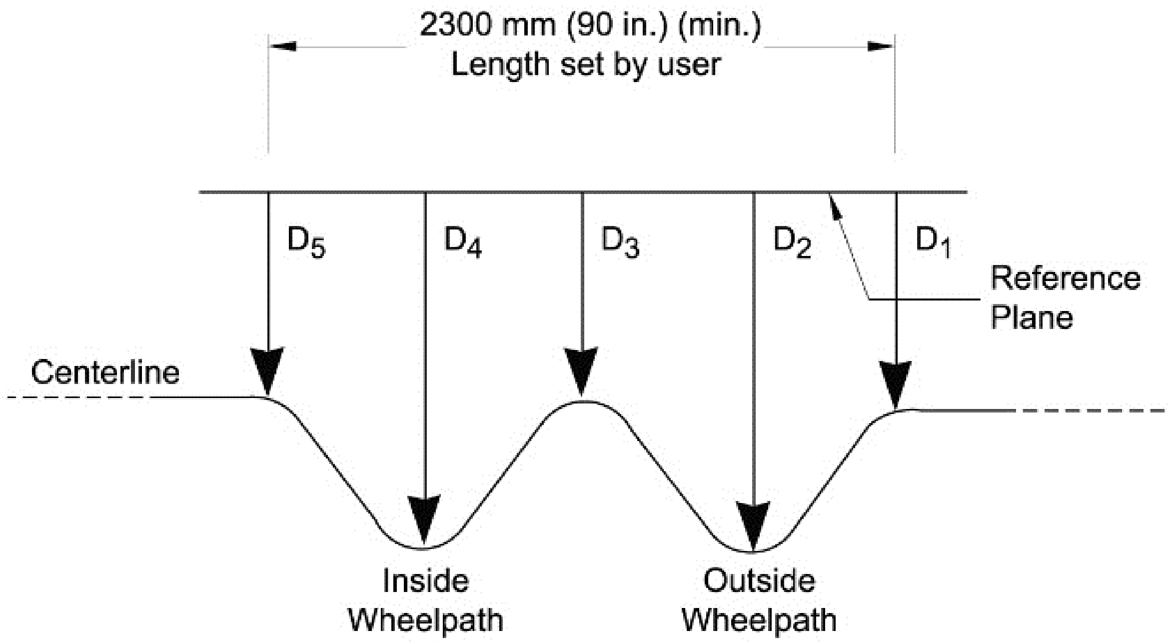

FIGURE 1 Old "rutting" standard.

The cracking standard (R 55) was designed to automatically assess the amount of asphalt cracking in different locations on the pavement. Like the current rutting standard, this procedure is useful, however, technological advances allow for improved collection of data, typically in the form of images that can provide detailed information about pavement condition.

The ETG developed new standards for rutting and pavement surface cracking (see FIGURE 2). In both cases, the ETG considered a need to split the standards into data collection and analysis pieces. The advantage of separating these components is the ability to refresh the standards independently as technology changes. Another advantage of this approach is that additional analysis standards can be developed based on the data-collection standard. As an example, the transverse profile data could be used both for rutting, and determination of cross-slope or crown-shape or edge drop-off, by creating specific analysis standards to accommodate these needs. On the cracking side, pavement images might be assessed for cracking at a level of detail appropriate for project-level analysis, and a separate standard could use the same initial data to generate summary statistics appropriate for federal funding needs input. The separation of data collection and analysis standards worked successfully when developing the pavement longitudinal profile (i.e. pavement smoothness) standards.

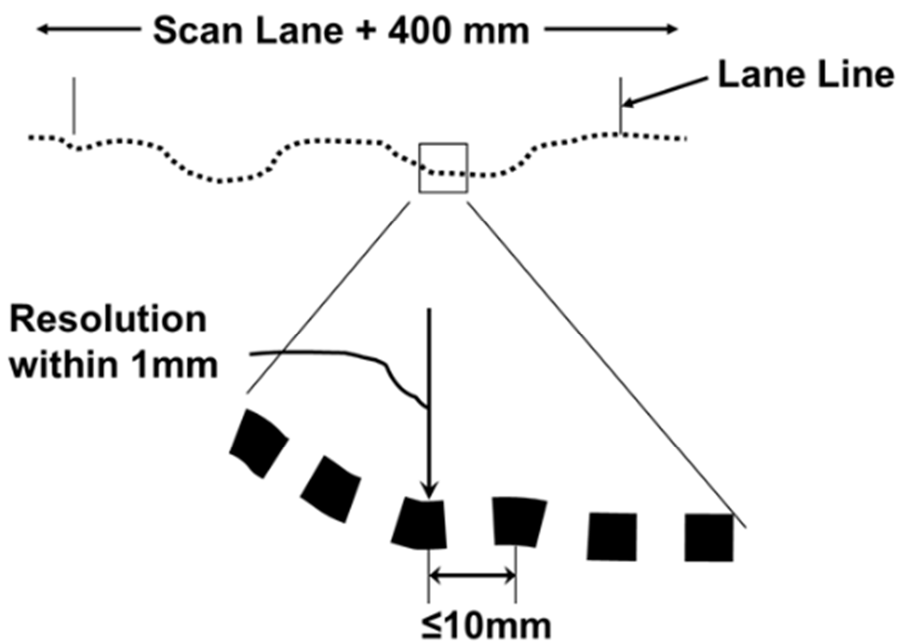

FIGURE 2 New transverse profiling and analysis standards.

For Collecting the Transverse Pavement Profile (PP 70), the standard assumes relative elevation points across the lane (actually 4 m or more to cover the lane) are collected with vertical resolution not worse than 1 mm and spaced no more than 10 mm apart across the lane. These points should be collected so that they are within +/-5 degrees perpendicular to the centerline of the road (see FIGURE 3 below). The interval, or how frequently the transverse profile is measured, is 3 m or less for network analysis and 0.5 m or less for project analysis purposes. The collection operation should occur at or near prevailing highway speeds. Output from this standard is a series of points giving position on the road in two-dimensional space and an elevation for each one.

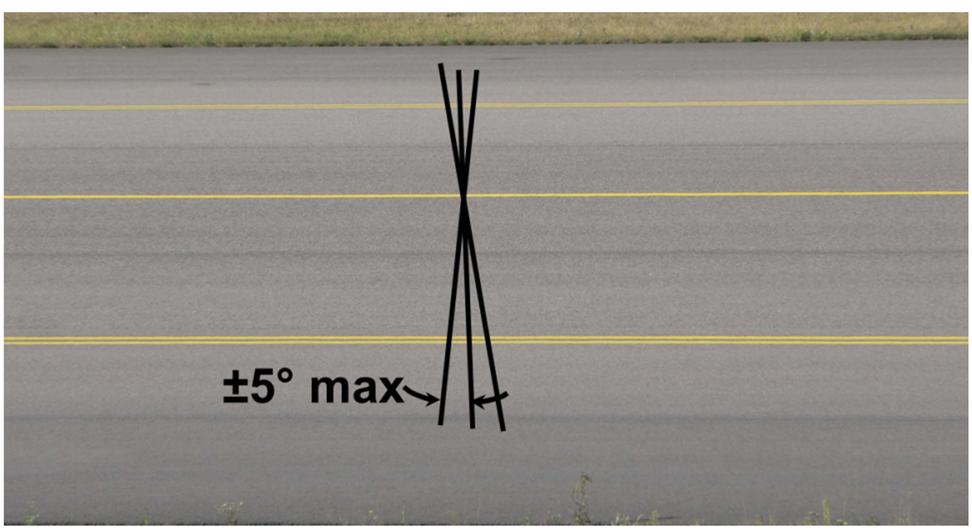

FIGURE 3 Transverse profile capture.

Using the data collected from PP 70, a second standard has been created, called Determining Pavement Deformation Parameters and Cross-Slope from Collected Transverse Profiles (PP 69), which describes different data reduction methods to compute statistics intended to identify pavement deformation and surface geometry. For example, the standard utilizes the transverse profile to calculate a cross-slope estimate by averaging the elevations on the two half-lanes and determining the slope of the connecting line (see FIGURE 4 and FIGURE 5). Similarly, the standard defines a new term called Percent Deformation as the difference between the straight-line length and the profile length of a section of pavement divided by the straight-line length multiplied by 100. A road with a linear cross-slope would be 0%. As the cross-slope becomes less linear, this value will increase and thus indicates the extent of deformation. Another calculation provides for "rut depths" that is similar to existing 5-point methods, but addresses many of the short comings by taking advantage of the additional points collected across the pavement (see FIGURE 6). This method averages certain areas to define the five points used in the rut calculation. The standard also provides a method to compute the area of ruts for estimating repair costs (see FIGURE 7) which is similar to the percent deformation. The standard allows for individual wheelpath ruts and other rut configurations such as the single rut in the middle of the lane.

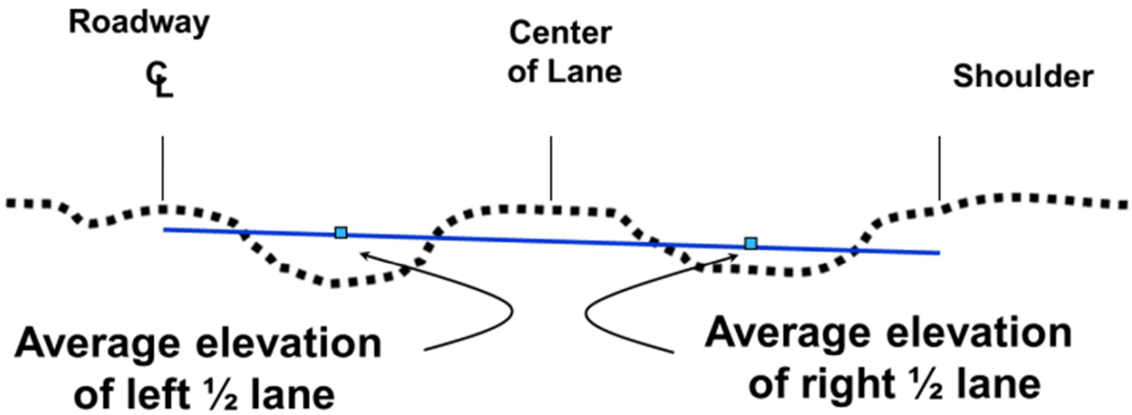

FIGURE 4 Calculating cross-slope.

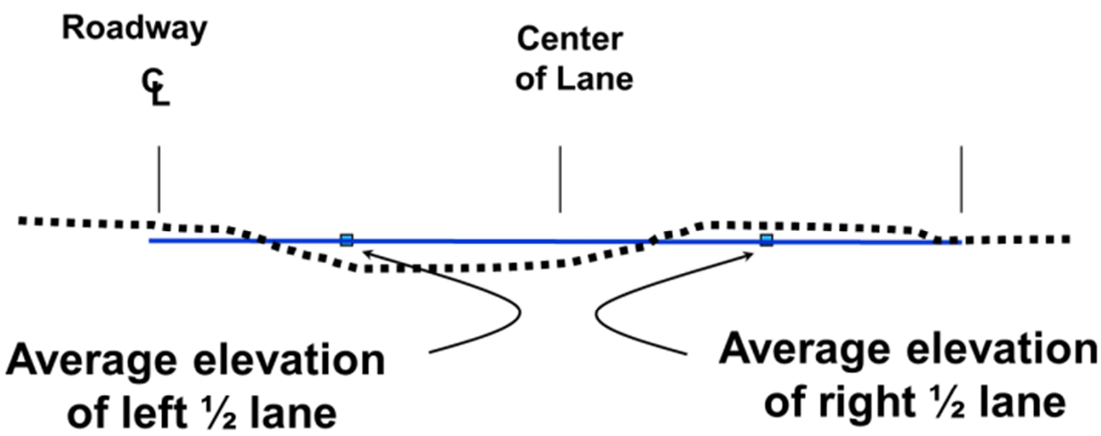

FIGURE 5 Calculating cross-slope.

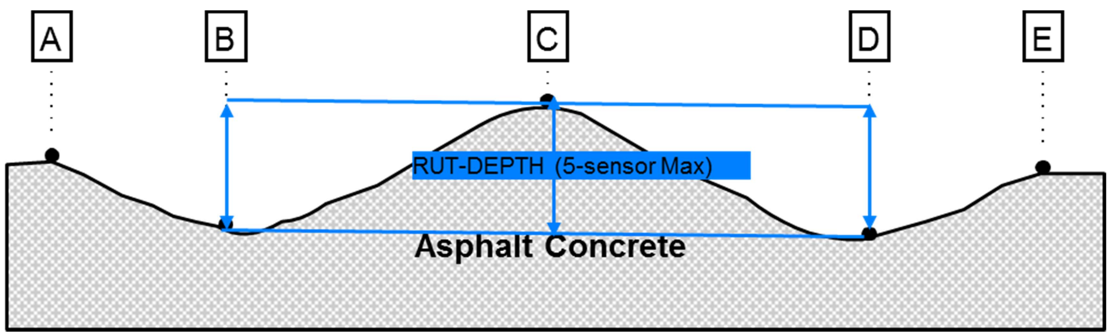

FIGURE 6 Maximum rut depth.

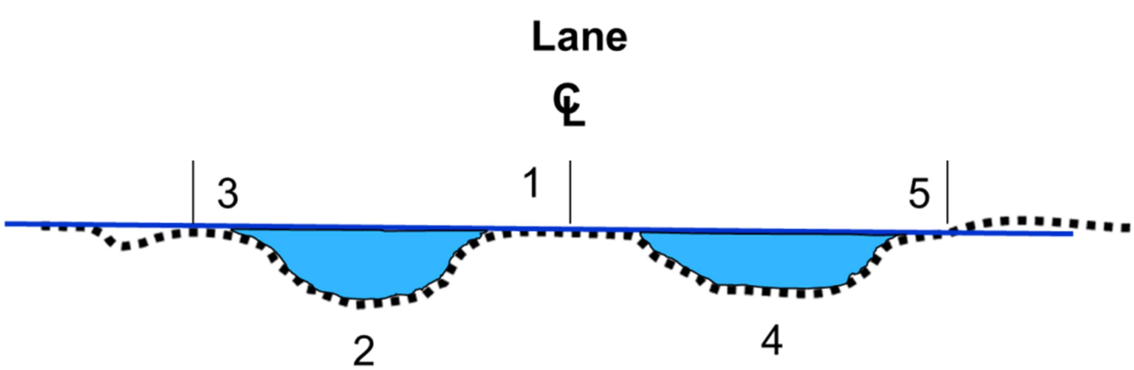

FIGURE 7 Rut area.

The other focus area for the ETG was pavement cracking. The ETG created two new standards. The first standard, Collecting Images of Pavement Surfaces for Distress Detection (PP 68), establishes the requirements of images (visual and infrared) such that they can be used by automated procedures to identify and categorize cracks. Again, the area collected should be wide enough to ensure the whole lane will be collected. The standard also contains a number of performance validation requirements, but indicates that these are, at this point, tied to the analysis needs.

The second standard, entitled Quantifying Cracks in Asphalt Pavement Surfaces from collected images Utilizing Automated Methods (PP67), describes a means to quantify and classify cracks (see FIGURE 8). Five zones are used in summarizing cracks with Zone 1 between the centerline and left wheelpath, Zone 2 as the left wheelpath, Zone 3 between wheel paths, Zone 4 as the right wheelpath, and Zone 5 between the edge line and the right wheelpath. Cracks are defined as pavement fissures at least 0.3 m long. The crack terminus is less than 1 mm wide; where the crack crosses a zonal boundary, or where cracks intersect. The width of a crack is defined as the average distance from crack edge to crack edge measured at 3 mm or less intervals. Three different classifications of cracks are defined as transverse, longitudinal and pattern. Transverse cracks must have an angle based on its endpoints of between 80 and 100 degrees relative to the direction of the centerline. Longitudinal cracks are defined as having an angle of +/-10 degrees relative to the centerline. Pattern cracks are defined as any other crack that does not meet transverse and longitudinal crack criteria. In all cases, the extent of cracks is the summed length of cracks within each zone. The extent is the average width within a zone. Cracks wider than 25 mm are treated as sealed cracks and are excluded. The standard offers a means to normalize reported cracking of systematic temporal comparisons. The standard also includes validation requirements that themselves still require confirmation.

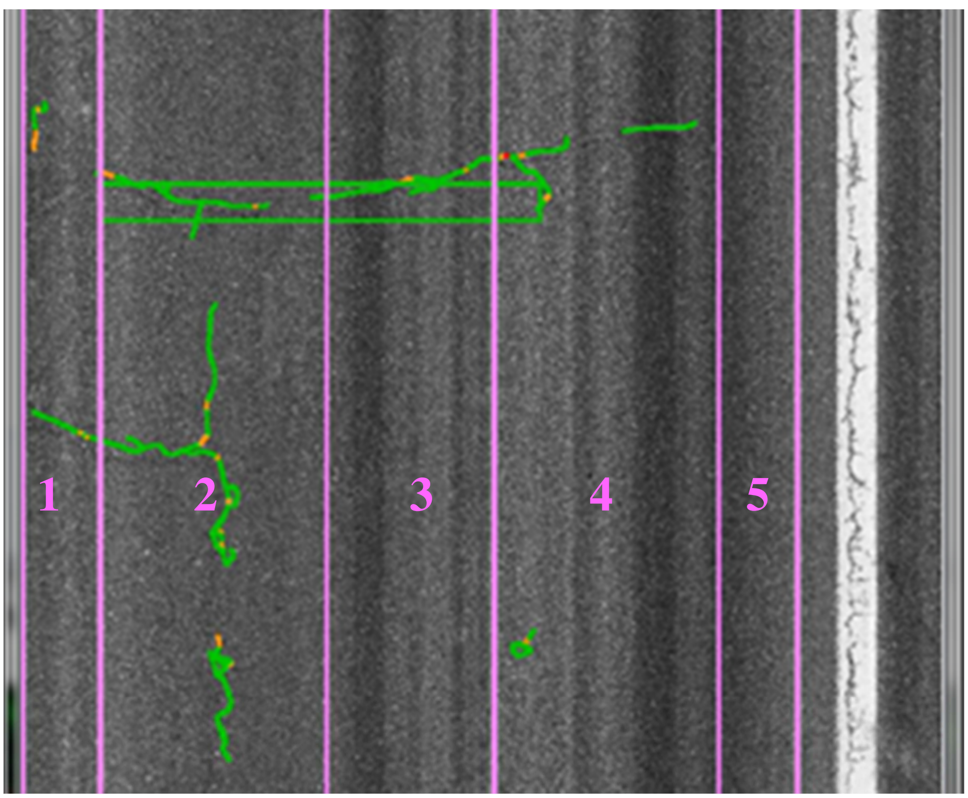

FIGURE 8 New images analysis standard for cracking.

TPF-5(299), IMPROVING THE QUALITY OF PAVEMENT SURFACE DISTRESS AND TRANSVERSE PROFILE DATA COLLECTION AND ANALYSIS

Expanding on these new protocols and the technical capabilities of systems to collect and analyze pavement evaluation data, many State Highway Agencies (SHA) are in the process of assessing this technology for supporting their data collection needs. With these needs in mind, a pooled fund study (TPF-5(299)) has been established to:

- Identify data collection integrity and quality issues
- Identify data analysis needs
- Suggest approaches to addressing identified issues and needs

As examples, initial studies are underway to evaluate the application of the AASHTO cracking protocols manually, as part of a validation/verification effort. Similarly, a study is being pursued to create a mechanical means for verifying precision and bias of transverse profile data. Through efforts and studies like these, the SHAs and the FHWA will:

- Initiate and monitor projects intended to address identified issues and needs
- Disseminate results
- Assist in solution deployment

CONCLUSIONS AND RECOMMENDATIONS

The transportation industry continues to recognize the need for higher quality pavement evaluation data. Protocols have been updated to take advantage of the technological advancements. Efforts are now getting underway to identify what gaps remain and evaluate how best to address these issues.

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