Analysis of Water Safety Plan costs from case studies in the Western Pacific Region
Zai Kang Chang, Mien Ling Chong and Jamie Bartram

ABSTRACT
Unsafe water remains a significant public health threat in high and low income countries. The World Health Organization (WHO) promotes Water Safety Plans (WSPs) as the most effective means of consistently ensuring the safety of a drinking-water supply. Although health benefits of WSP implementation have been shown, there is a lack of information relating water supplier characteristics to expected costs. Costing practices were adapted from food quality management studies and applied to six water suppliers from the Western Pacific Region, as designated by WHO. The explanation building procedure was used to develop understanding of relationships between drinking-water supply agency (DWSA) characteristics and WSP implementation costs. The results indicate that costs associated with WSP implementation are expected to be low for developed DWSAs; however, for developing DWSAs, there is high variability in costs which indicates further research may not improve generalized WSP cost estimations. Furthermore, developing DWSAs experience large and highly variable capital and operational monitoring costs. The capital and operational monitoring improvements are necessary to achieving a safe water supply and may require ongoing financial and technical resources to execute.

Key words | cost, drinking-water, HACCP, risk management, Water Safety Plans, water safety

INTRODUCTION
Globally, the disease burden from poor water, sanitation and hygiene is estimated to be 5.7% of the total disease burden (Prüss et al. 2002). Improvements in water supply offer an effective means of reducing the incidence of diarrhoeal diseases (Fewtrell & Colford 2004).

In 2010, there were an estimated 6.09 billion people using improved water supplies (World Health Organization/UNICEF 2012), however, using an improved water supply does not necessarily guarantee safe water (Onda et al. 2012). In some areas with piped distribution systems, illegal connections, utility staff errors, and breaks in the distribution system are not only potential sources of public health threats but also sources of economic loss. Losses from non-revenue water are prevalent among utilities in developing countries, with as much as a third of production being lost in the form of physical and revenue losses (The World Bank 2004). Drinking-water can be seen as a public good and faults in its quality or supply may have adverse consequences for political entities. By managing risks to water safety, drinking-water supply agencies (DWSAs) have the opportunity to mitigate political risk, improve financial sustainability and increase safety of the supplied water.

The World Health Organization (WHO) introduced the concept of Water Safety Plans (WSPs) in 2004 in the third edition of its Guidelines for Drinking-water Quality as ‘the most effective means of consistently ensuring the safety of a drinking-water supply’. A WSP is a comprehensive risk management approach that provides a template for DWSAs to assess, prioritize and manage drinking-water contamination risks found in the catchment, treatment systems and distribution networks in an integrated manner. The WSP is associated with health-based targets and a system of independent surveillance to constitute a framework for safe drinking-water. This approach prioritizes...
risks to safe water supply from a public health perspective and has been shown to reduce non-compliance with water quality standards and incidence of diarrhea (Gunnarsdóttir et al. 2022a, b). Non-health improvements, including improved process operations and management (Jayaratne 2008; Gunnarsdóttir et al. 2022a, b), have also been shown.

WSPs draw on approaches from risk and quality management systems, such as the Hazard Analysis Critical Control Point (HACCP) system, principles such as the multiple barrier principle and earlier-established procedures such as sanitary inspections. WSPs and applications of the HACCP system will collectively be referred to herein as ‘WSPs’.

In assessing the efficiency of WSPs, it is necessary to weigh benefits against costs of implementation. However, published literature regarding WSP costs is generally lacking. A WHO report to the European Commission suggests there is limited evidence to support the idea that WSP-type approaches are cost effective and evidence concerning the cost effectiveness (World Health Organization 2007) should be developed. Case studies from Martel et al. (2006) and Gerber (2010) offer examples of individual WSP implementation costs.

Understanding relationships between DWSA characteristics and the resulting WSP implementation costs can improve the ability of DWSAs to predict WSP implementation costs.

The objective of the research is to improve a priori estimations of WSP implementation costs by defining cost components, providing example costs, and explaining relationships between costs and DWSA characteristics.

METHODS

Study design

The research employed a case study approach because the phenomenon under study was not readily distinguishable from its context (Yin 2003). Case studies typically focus on understanding dynamics within single settings and collecting data through multiple means (Eisenhardt 1989).

The study included cases from the Western Pacific region that have implemented WSPs between 1999 and 2011: Yarra Valley Water (YAR) in Melbourne, Australia; Pakse Provincial Water Supply State-Owned Enterprise (PAK) in Pakse, Laos; Koror-Airai Public Water Supply (KOR) in Koror, Palau; Maynilad Water Services, Inc. (MAY) in Manila, Philippines; Dasmarñas Water District (DAS) in Cavite, Philippines; Thua Thien Hue Water Supply & Sewerage Company (THU) in Hue City, Vietnam and cost information for the corresponding surveillance agencies. Besides YAR and the Victoria Department of Health, all DWSAs and surveillance agencies in this research were associated with WHO Western Pacific Regional Office’s (WPRO) Asia Pacific Water Safety Plan Network.

Case study best practices suggest cases should be selected based upon pre-defined criteria (Yin 2003) and can be chosen for theoretical rather than statistical reasons (Eisenhardt 1989). The cases in this study were chosen based on their degree of ‘development’, implementation of a WSP, and their ability to provide insight into the DWSA and its WSP implementation costs. DWSAs at various levels of development were chosen to develop hypotheses on the relationship between DWSA development and benefits and accrued costs.

Data collection

Multiple sources of evidence were used to develop converging lines of inquiry (Yin 1994) and as a means of verification. Data collection methods included literature review, standardized solicitations, questionnaires and semi-structured interviews.

A desk-based review collected academic and gray literature from: academic journal catalogues; databases such as ECOLEX; webpages of water-related organizations such as the Secretariat of the Pacific Community, WHO, relevant ministries and the Australian Agency for International Development; and trade magazines such as the International Water Association’s Water21. The review returned documents such as national drinking-water quality standards, legislation, journal articles, DWSA operating procedures, WSPs, conference notes and country reports. Literature review documents are referenced.

Solicitations and questionnaires were piloted and content was subsequently adapted.
Regulatory agencies, ministries, utilities, and other organizations working in the field such as WHO were solicited through scripted communications. Positive responses were followed up by a description of the study and an email questionnaire or interview.

Semi-structured interviews were performed in person, by e-mail or telephone. The in-person interviews were primarily conducted from the WHO Pacific Regional Office in Manila, Philippines. Data collection from participants in Laos and Vietnam were administered through their respective WHO country offices. The staff were made knowledgeable about the objectives of the research prior to administering the interviews with the participants.

The research involved human subjects and required approval from the University of North Carolina Office of Human Research Ethics (study number: 11-1022).

Costing and DWSA characteristics

An accounting approach was used to determine WSP implementation costs in each case by collecting cost information on activities that had already occurred or were ongoing. The financial costs and cost savings to DWSAs and surveillance agencies of WSP activities are defined here as the monetary value of any new activities or changes in existing activities resulting from the WSP. This analysis defined costs as the financial costs of implementation against a counterfactual scenario in which there was no WSP implementation. WHO guidelines for drinking-water quality suggest that an authority independent from the water supplier be responsible for surveillance (World Health Organization 2021). Costs to surveillance agencies represent the monetary value of activities that explicitly assist WSP development and the cost of any changes in surveillance activities arising as a result of WSP implementation. Other external organizations can play a role in facilitating the implementation of WSPs and the value of their services are described herein as external costs. For cost calculation purposes, costs of unknown value were treated as zero values.

Costing methods used in this research are adapted from those in costing studies of HACCP in the food industry (Roberts et al. 1996; Jensen et al. 1998; Krieger et al. 2007). Large capital costs for infrastructure upgrades were annualized over the lifespan of the upgrade using a capital recovery factor and a weighted-average interest rate of 5%. We adjusted for inflation using a GDP deflator. All costs are in 2009 international dollars.

Costs and savings were categorized as non-recurring or recurring and as Basic or DWSA-specific. Costs related to a continued change in resource inputs such as increased operational monitoring activities were classified as recurring. Costs of discrete research activities, one-time training and WSP initial development costs were classified as non-recurring. Costs and savings were also separated into Basic WSP and DWSA-specific. A Basic WSP cost or saving is one of quality assurance and includes essential WSP activities, such as drinking-water quality monitoring (DWQM), WSP training and auditing. A DWSA-specific cost or saving is one that depends on context and varies among DWSAs. Examples include capital expenditures, supporting programs and control measures. DWSA-specific cost components are largely costs of achieving water quality targets; representing expenditures required to provide a consistently safe supply of water.

DWSAs were categorized as ‘developed’ if they met criteria of operational efficiency (employee per connection ratio below five employees per 1,000 connections (Tynan & Kingdom 2002)) and effectiveness (consistent supply of an adequate amount of safe drinking-water for which certified total quality management (TQM) systems such as ISO 9001 serve as an indicator). Other DWSAs were categorized as ‘developing’ (Table 1).

Explanation building

Qualitative data analysis of case studies consists of examining, categorizing, or otherwise recombining evidence to address the initial purpose of the study (Yin 2003). Relationships between costs and DWSA characteristics were formed using explanation building, a specific form of pattern-matching analysis. Explanation building is a hypothesis-generating process that takes an iterative approach to develop a set of causal links (an explanation) about the phenomenon under research. An initial theoretical statement is constructed based on theory or previous evidence and is then used to compare an empirically based pattern with the predicted one (Trochim 1989). The goal of this process is not always to answer the initial proposition, but to develop the
idea for further study (Yin 1994). The result is an explanatory framework of the cost and benefit patterns observed in the sample and provides evidence for hypotheses theoretically applicable to DWSAs outside the sample. The results of explanation-building are generally presented as a narrative.

Two initial theoretical statements were examined: ‘more developed DWSAs incur lower costs from WSP implementation compared to developing DWSAs’ and ‘the total cost of DWQM decreases as a result of WSP implementation’.

**RESULTS**

**WSP implementation costs**

Cost information is presented for the DWSAs in Table 2 and for the WSP activities of the six corresponding surveillance agencies in Table 3.

**Explanation building for cost patterns**

The two developed DWSAs incurred lower DWSA-specific costs compared to developing DWSAs. Explanations for this pattern were seen when costs were further analyzed.

A comparison of Basic WSP, non-recurring costs across both DWSA groups revealed no pattern supporting the proposition that more developed DWSAs incur lower Basic WSP, non-recurring costs. Staff time and WSP training made up the majority of the Basic WSP non-recurring costs and were the most prevalent cost types among all DWSAs. This resulted in a limited range of cost magnitudes in this category. Table 4 shows a measure of variability across the cost categories.

The non-recurring, DWSA-specific costs of the developing group varied from US$0.0214/connection for PAK to US$36.9/connection for KOR. This difference was due to varied supporting programs and capital costs. Figure 1 shows the percent contribution of Basic WSP and DWSA-specific costs to total non-recurring costs.

Basic WSP recurring costs varied widely across all DWSAs and within DWSA groups. There was no apparent association between the number of Basic WSP activities performed by the DWSA and the Basic WSP cost totals.

The DWSA-specific recurring costs per connection for all developing DWSAs were higher than those of the developed group. Within the developing group, these costs differed widely and comprised the majority of total recurring costs.

**DISCUSSION**

**Findings**

The study by Martel et al. (2006) was the only other published work to document costs of multiple WSPs available
Table 2 | WSP implementation costs for the six water suppliers and any external agencies (2009 international dollars). Costs per connection are in parentheses

<table>
<thead>
<tr>
<th>DWSA name</th>
<th>Yarra Valley Water (YAR)</th>
<th>Maynilad (MAY)</th>
<th>Koror-Airai (KOR)</th>
<th>Dasmariñas Water District (DAS)</th>
<th>Thua Thien Hue Water Supply and Sewage Co. (THU)</th>
<th>Pakse Provincial Water Supply (PAK)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic WSP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff time non-recurring</td>
<td>18,360 (0.0268)</td>
<td>58,538 (0.0624)</td>
<td>Unknown</td>
<td>6,820 (0.0686)</td>
<td>14,990 (0.101)</td>
<td>2,760 (0.0281)</td>
</tr>
<tr>
<td></td>
<td>22,250 (0.0324)</td>
<td>700 (0.000746)</td>
<td>0</td>
<td>330 (0.00332)</td>
<td>0</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Drinking-water quality monitoring</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-recurring</td>
<td>0</td>
<td>0</td>
<td>Unknown</td>
<td>0</td>
<td>Yes, unknown</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>Unknown</td>
<td>0</td>
<td>16,950 (0.115)</td>
<td>1,220 (0.0125)</td>
</tr>
<tr>
<td><strong>WSP training</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-recurring</td>
<td>54,520 (0.0795)</td>
<td>16,112 (0.0172)</td>
<td>0</td>
<td>7,200 (0.0724)</td>
<td>1,570 (0.0106)</td>
<td>280 (0.00285)</td>
</tr>
<tr>
<td></td>
<td>4,420 (0.00644)</td>
<td>0</td>
<td>0</td>
<td>330 (0.00332)</td>
<td>12,230 (0.0827)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Auditing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-recurring</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14,610 (0.0213)</td>
<td>1,710 (0.00182)</td>
<td>0</td>
</tr>
<tr>
<td><strong>DWSA-specific</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control measure non-recurring</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,680 (0.0169)</td>
<td>155,080 (1.05)</td>
<td>−5,370 (−0.0548)</td>
</tr>
<tr>
<td><strong>Operational monitoring</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-recurring</td>
<td>0</td>
<td>0</td>
<td>Unknown</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>Unknown</td>
<td>17,200 (0.173)</td>
<td>Yes, unknown</td>
<td>5,490 (0.0536)</td>
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<tr>
<td>Supporting program non-recurring</td>
<td>0</td>
<td>0</td>
<td>138,330 (36.9)</td>
<td>2,520 (0.0253)</td>
<td>60,360 (0.408)</td>
<td>1,880 (0.0192)</td>
</tr>
<tr>
<td></td>
<td>51,610 (0.0752)</td>
<td>0</td>
<td>5,000 (1.34)</td>
<td>0</td>
<td>13,320 (0.0901)</td>
<td>6,520 (0.0666)</td>
</tr>
<tr>
<td><strong>Capital maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-recurring</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5,870 (0.0591)</td>
<td>0</td>
<td>220 (0.0023)</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>5,400 (1.44)</td>
<td>180 (0.00181)</td>
<td>2,079,190 (14.1)</td>
<td>8,530 (0.0871)</td>
</tr>
<tr>
<td><strong>Total non-recurring cost</strong></td>
<td>72,890 (0.106)</td>
<td>74,650 (0.0796)</td>
<td>138,330 (37.0)</td>
<td>22,410 (0.225)</td>
<td>76,920 (0.520)</td>
<td>5,140 (0.0523)</td>
</tr>
<tr>
<td>Basic WSP</td>
<td>72,890 (0.106)</td>
<td>74,650 (0.0796)</td>
<td>Unknown</td>
<td>14,020 (0.141)</td>
<td>16,560 (0.112)</td>
<td>3,040 (0.0309)</td>
</tr>
<tr>
<td>DWSA-specific</td>
<td>0</td>
<td>0</td>
<td>138,330 (36.9)</td>
<td>8,390 (0.0844)</td>
<td>60,360 (0.408)</td>
<td>2,100 (0.0214)</td>
</tr>
<tr>
<td><strong>Total recurring costs</strong></td>
<td>92,890 (0.135)</td>
<td>2,410 (0.00257)</td>
<td>10,040 (2.78)</td>
<td>19,720 (0.199)</td>
<td>2,279,800 (15.4)</td>
<td>14,390 (0.147)</td>
</tr>
<tr>
<td>Basic WSP</td>
<td>41,280 (0.0602)</td>
<td>2,410 (0.00257)</td>
<td>Unknown</td>
<td>660 (0.00664)</td>
<td>32,210 (0.218)</td>
<td>1,220 (0.0125)</td>
</tr>
<tr>
<td>DWSA-specific</td>
<td>51,610 (0.0752)</td>
<td>0</td>
<td>10,400 (2.78)</td>
<td>19,060 (0.192)</td>
<td>2,247,590 (15.2)</td>
<td>13,170 (0.134)</td>
</tr>
<tr>
<td><strong>External costs</strong></td>
<td>Unknown</td>
<td>4,758 (0.00507)</td>
<td>Unknown</td>
<td>0</td>
<td>100 (0.000676)</td>
<td>2,944 (0.0300)</td>
</tr>
</tbody>
</table>

*Negative costs represent cost savings.*
to the authors at the time of writing. The WSP initial development costs in the Martel et al. (2006) study differed widely and were not consistent with the analogous costs of the developed DWSAs in this study. The explanation for the differences among the WSP initial development costs from Martel et al. (2006) were also dissimilar and were due to the prior implementation of other quality management systems and the extent to which external service providers were used. Recurring costs in the Martel et al. (2006) study differed based on the extent to which additional risk management activities were implemented. This pattern was evidenced in this study by the lack of DWSA-specific, non-recurring costs of MAY and YAR.

A preliminary evaluation of WSP implementation in Iceland showed limited resources to be a challenge for the implementation of auditing functions (Gunnarsdóttir 2008). DAS was unable to begin internal training and auditing programs due to inadequate technical capacity among the staff and MAY and DAS were unable to complete capital improvements due to lack of funding. Together, this suggests the implementation of both Basic and DWSA-specific activities may be limited by financial and technical resources.

The DWSA-specific costs for developing DWSAs differed widely. Similarly, costing studies in the food industry found uncertainty in estimating individual HACCP implementation costs because of context dependence (Jensen et al. 1998).

Comparisons in costs to surveillance agencies were not performed because of the difference in the nature and scale of their involvement in WSP activities. For example, the Department of Health in Victoria developed legislation that required WSP implementation while the Environmental Quality Protection Board of Palau spent staff time to support the development of the Koror-Airai WSP. As in other industries, it is generally expected that if WSPs

<table>
<thead>
<tr>
<th>Surveillance agency name</th>
<th>Philippine Department of Health</th>
<th>Victoria Department of Health</th>
<th>Thua Thien Hue Preventive Medicine Center</th>
<th>Philippine Department of Health</th>
<th>Lao P.D.R. Ministry of Health</th>
<th>Palau Environmental Quality Protection Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-recurring costs</td>
<td>Unknown</td>
<td>4,254,100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>200</td>
<td>Unknown</td>
<td>Unknown</td>
<td>9,000</td>
</tr>
<tr>
<td>Recurring costs</td>
<td>2,400&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Unknown</td>
<td>24,210</td>
<td>2,400&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Unknown</td>
<td>5,000</td>
</tr>
</tbody>
</table>

<sup>a</sup>Costs apply to the state of Victoria.

<sup>b</sup>Costs apply to all Water Safety Plans in the Philippines.

| Basic WSP non-recurring costs | 4.56 |
| DWSA-specific non-recurring costs | 1,720 |
| Basic WSP recurring costs | 84.5 |
| DWSA-specific recurring costs | 202 |
become regulatory requirements, regulatory bodies and surveillance agencies will incur associated costs.

Transferability of findings

While the explanation building method provided evidence for cost patterns applicable to DWSAs outside the study, the qualitative nature of the study limited the relevance of the WSP implementation cost information to the selected setting. Other limitations on transferability of results to other settings stemmed from participant biases, uncertainty in data quality, and issues in WSP cost comparability.

Some participants may have exhibited social desirability bias towards reporting lower WSP costs. Multiple strategies were used to control the effect of biases. First, standardized questionnaires were used to control the expression of inquiry. Secondly, verification was sought by asking participants to provide reference documents. Third, the solicitation stated that participants would remain unidentified. Lastly, the objectives of the study and output were clearly stated so as to reduce the perception that anything could be gained from responding inaccurately.

YAR, MAY and DAS provided more sources of costing information compared to KOR, PAK and THU. All costs in the latter three DWSAs were not known, which may limit the validity of the results.

While the research did not seek a regionally representative set of water suppliers, diversity in the level of ‘development’ of DWSAs was sought. A more robust characterization of DWSA development would allow for improved transferability of the findings to other settings. Costs were made comparable through the use of international dollars. However, differences in costs of available goods and labor were not accounted for, which may affect the validity of the comparison across currencies.

Future research

Future qualitative studies can benefit from improving data collection methods by performing focused interviews with participants at different levels within each DWSA organization, and maintaining the quality and number of sources of evidence across cases. In order to promote comparability, studies should account for the degree of WSP implementation or create an operational definition of WSP implementation costs. Alternatively, longitudinal studies may be used to characterize the WSP costs over time. Creating a more comprehensive set of DWSA groupings and using a case selection strategy with a strong analytical basis can improve the generalizability of the findings. Due to the unknown degree of actual WSP implementation and variability in the DWSA-specific costs, researchers may want to determine the timing, extent and challenges in DWSA implementation of WSP findings.

While compliance, public health and supplier benefits of WSP implementation have been documented (Gunnarsdóttir et al. 2022a, b), economic analyses can quantify monetary benefits to society as a whole. HACCP studies in the food industry quantify costs and benefits of quality management regulations (Crutchfield et al. 1997; Antle 1999) and produced guides for doing so (MacDonald & Crutchfield 1996; Krieger et al. 2007).

Significance of contributions to the literature

This paper makes two contributions to the literature. It provides more cases for the small body of empirical WSP costing studies; and provides evidence for relationships between DWSA characteristics and WSP costs. Both are important for improving cost estimations of WSP implementation and determining cost effectiveness at DWSA and policy levels. Rather than characterizing WSP costs directly, this research more precisely characterizes costs of securing safe water. Qualitative studies of this type provide a theoretical basis for larger-scale quantitative costing studies.

CONCLUSION

Suppliers of all types can expect initial WSP development costs. The relatively low development costs suggest that barriers to starting the WSP process may not be strictly financial. Subsequent costs of maintaining drinking-water quality targets are expected to vary based on context.

Developed suppliers may find it difficult to predict ongoing costs of quality assurance although costs are thought to correlate with the robustness of the quality assurance programs. The costs of securing water quality are lower...
for developed suppliers compared to developing suppliers because many of the activities have already been performed in the better maintained systems.

For developing suppliers, WSPs appear to elicit activities to achieve water quality. These capital and operational monitoring improvements represent a majority of the WSP costs, vary widely and can be large. Developing suppliers may require initial and ongoing financial or technical resources from external sources to execute the necessary improvements. Due to the variability in the context-dependent costs for developing suppliers, future costing studies may not improve estimations for WSP implementation costs.

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