Urban crack users in The Netherlands: Prevalence, characteristics, criminality and potential for new treatments
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Estimating the Prevalence of Crack Dependence Using Capture-Recapture with Institutional and Field Data: A Three-City Study in the Netherlands

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ABSTRACT

The aim of this study was to estimate the prevalence of crack dependence in the three largest Dutch cities (Amsterdam, Rotterdam, The Hague), stratified by gender and age. Three-sample capture-recapture, using data (collected between 2009 and 2011) from low threshold substitution treatment (n = 1,764), user rooms (n = 546), and a respondent-driven sample (n = 549), and applying log-linear modelling (covariates: gender, age, and city), provided a prevalence rate of 0.51% (95% CI: 0.46%–0.60%) for the population aged 15–64 years, with similar estimates for the three cities. Females (23.0% of total estimate) and younger crack users (12.8% aged <35 years) might be underrepresented in drug user treatment services.

**Keywords:** capture-recapture, crack dependence, prevalence, gender, respondent-driven sampling, mark-recapture, problem drug users
3.1. INTRODUCTION

There has been a growing concern in Europe during the past decades about the use of crack cocaine (crack), being associated with a wide range of health and social problems for the individual, and with significant public order consequences for society (Connolly, Foran, Donovan, Carew, & Long, 2008; EMCDDA, 2007; Hoogenboezem, Ensdorff, & Croes, 2008; Ilse, Prinzleve, Zurhold, & Haasen, 2006; Oliveira, 2010; Ouwehand, Kuipers, Wisselink, & Van Delden, 2010). Treatment demand data and self-reported use in purposive drug user samples indicate that the prevalence of crack use varies widely between European countries and cities (Eisenbach-Stangl & Moskalewicz, 2009; EMCDDA, 2011), as well as between cities within the same country (Barrio, De la Fuente, Royuela, Díaz, & Rodríguez-Artalejo, 1998; Fischer et al., 2006; Stoever, 2002). In the Netherlands (population 16.7 million), cocaine treatment demand doubled during the past decade (LADIS, 2006; Ouwehand et al., 2010). In 2010, over 9,400 patients were classified as having cocaine use as their primary drug-use related problem (mean age 36.6 years, 17% female), including approximately 4,300 crack users (Ouwehand et al., 2010).

Crack users are predominantly characterized as a population of chronic, problematic, and marginalized users (Coumans, 2005; Nabben & Korf, 1999; Ouwehand et al., 2010; Van der Poel, Barendregt, & Van de Mheen, 2006), and crack use is very low among recreational drug users in the Netherlands. For instance, in a national survey among clubbers, crack use lifetime prevalence was 1.2%, and last month prevalence 0.1% (vs. 16.0% and 4.8% respectively for cocaine powder; Van der Poel et al., 2010). In the most recent Dutch general population survey (15–64 years), cocaine lifetime prevalence was 5.2% and last month prevalence 0.5%; the number of last month cocaine users was estimated at 55,000 (95% CI: 3,7000–78,000; Van Rooij, Schoenmakers, & Van de Mheen, 2011). As is common in general population or household surveys, no distinction was made between cocaine powder and crack. Moreover, crack users are presumably underrepresented in general population surveys, due to their marginalized lifestyle (e.g., homelessness), and it is questionable whether reliable estimates can be calculated from such surveys. Consequently, alternative estimation methods are required. One alternative is the multiplier technique. If a specified proportion (p) of a population (N) has a specified characteristic (n), then the size of the population can be estimated using the following equation: N = (n) ∗ 1/(p), where the inverse of p is the multiplier. For example, the size of the population of crack dependent users could be estimated from the total number of crack dependent patients in treatment (n) and the intreatment rate (p). This requires both an appropriate patient registration system and a valid intreatment rate, for example, derived from a representative field (or community) sample.

In a recent Dutch study (Cruts & Van Laar, 2010), the multiplier method was applied to estimate the total number of ‘problem drug users’ in the Netherlands from treatment utilization reported in user samples (p) and treatment data (n). The number of ‘problem opiate users’ was estimated at 17,700 (95% CI: 17,300–18,100), and the number of ‘problem crack users’ who do not use opiates was estimated at 12,400 (95% CI: 10,300–15,600). However, as the authors note, the estimate for problem crack use was only tentative, largely because of doubts regarding the representativeness of the field samples of non-opiate users, and consequently of the multiplier (intreatment rate). The latter problem can be avoided by
applying capture-recapture (C-RC), a second alternative to assess under-ascertainment in general population surveys. In the presence of two or more datasets, like registration lists, C-RC can be used to estimate the size of the non-captured part of the population (e.g., persons not in treatment) and then of the total population, being the sum of all captured and non-captured persons. In many countries, C-RC has been applied to estimate the national, regional, or local number of problem drug users (Comiskey, 2001; Hickman et al., 2006, 2009; Stimson, Hickman, Quirk, Frischer, & Taylor, 1997; Vaissade & Legleye, 2009). Sometimes crack users are included in the estimated number of problem drug users, a target population that is often estimated through C-RC in Europe. For example, it was used to estimate the prevalence of problem opiate and cocaine users in three French cities, resulting in prevalence rates between 0.61% and 0.67% (Vaissade & Legleye, 2009).

Separate estimations for crack users are rare. Probably the only exception refers to the city of London, UK (Hope, Hickman, & Tilling, 2005), where C-RC with data from healthcare services, arrest referrals, and a community survey on injecting drug users was used to estimate the number of crack users, resulting in a prevalence rate of 1.5% (95% CI: 1.0%–3.2%) for the population aged 15–44 years. Assessing the extent of crack dependence is a considerable challenge as the information available is scarce. The aim of this study is to estimate the size of the population of crack dependent users, stratified by gender and age, in the three largest Dutch cities, namely Amsterdam, Rotterdam, and The Hague (1.9 million residents in total, representing 11.3% of the national population), by applying C-RC to data from institutional samples and respondent-driven field samples.

3.2. METHODS

C-RC can be applied to two or more data sources, the latter also being known as multiple capture. In the present study, we use three data sources for each city. In short, C-RC works as follows. The observed data from the three samples are ordered into a $2 \times 2 \times 2$ contingency table, in which the empty cell (i.e., the number of subjects not present in any of the three data sources) represents the unobserved population. With the C-RC method, the number of persons in the empty cell can be estimated. The inclusion of more than two samples allows for correction of potential dependencies between the samples by incorporating interaction terms in a log-linear model (Buster, 2001; Fienberg, 1972; Frischer et al., 1991). The log-linear model describes the probability to be in any particular cell of the contingency table in terms of main and interaction effects. It can be further extended by the inclusion of covariates, i.e., variables that to some extent explain the dependencies between the lists. Since different models can result in different population size estimates, it is important to select the best fitting model. The Bayesian Information Criterion (BIC) was used as selection criterion since it yields relatively simple models, thus diminishing the risk of instable estimates (Buster, 2001; Hook & Regal, 1995). The present study includes three samples of crack dependent users: a respondent-driven sample (RDS), low threshold substitution treatment centers, and consumption or user rooms.

RDS is a chain-referral method used for recruiting so-called ‘hidden populations,’ modified in order to minimize selectivity bias in referrals to new respondents ( Heckathorn, 1997, 2002; Johnston, 2008; Salganik, 2004). Details of data collection for this study have
been documented in a previous article (Oteo Perez, Korf, & Benschop, 2012). In brief, a small initial group of members of the target population identified through ethnographic fieldwork (seeds) were invited to participate in a survey. After having had their unique identifiers collected and answering a questionnaire, each respondent was asked to recruit a maximum of two other crack dependent users from their social network. Participants received an incentive for their participation in the survey and for each eligible person they had recruited. This process was repeated during the established six-month study period for each city. As a proxy for crack dependence, a frequency of use of at least two days per week in the last month was required for inclusion in the survey.

Substitution treatment (substitution) refers to low threshold outpatient facilities for opiate substitution treatment (mainly methadone and sometimes also heroin). In these programs drug use is tolerated, and crack use is very common among clients (Smit, Van Laar, & Wiessing, 2006). Other forms of (specialized) treatment for crack addiction were not chosen, because the number of patients is much smaller, and many are not current users. Subjects were included in the study if they were listed in the registration systems of these institutions with crack use as primary or secondary problem and had attended the service during the six-month study period.

User rooms are facilities where frequent drug users can administer their drugs under staff supervision, with the aim of reducing drug use-related street nuisance and health problems. Most visitors of user rooms are dependent crack users. A list of frequent crack users from every facility in each city was generated, with the exception of one user room for foreign undocumented drug users (in Amsterdam), for reasons explained below.

In sum, the criteria used as proxy for crack dependence were two or more days per week crack use in RDS, crack use as primary or secondary problem in substitution, and frequent crack use in user rooms. All subjects were at least 18 years of age. This study was part of the project ‘Prevalence, treatment needs and new pharmacotherapeutic treatment options for crack dependent people in the Netherlands.’ The full study design was approved by the ethical committee of the Faculty of Medicine of the University of Amsterdam.

The precision of C-RC estimates depends on the extent to which certain conditions are met (Buster, 2001; Chao, Lee, & Jeng, 1992; IWGDMF, 1995). We enumerate these assumptions, as well as our measures to comply with them or to minimize their violation.

1. **Perfect matching:** all true matches and only true matches must be identified. Standardized rules were followed to create unique identifiers, containing first four letters of last name, date of birth, and gender. Respondents in the RDS sample were asked to provide the data required for the unique identifier, verified by their ID or any other official document.

2. **Homogeneity:** individuals have the same inclusion probabilities (for all samples). Violation of this assumption is tackled by including covariates and their interaction terms with the sources in the log-linear model, since these allow for individual differences in the inclusion probabilities (Tilling & Sterne, 1999). For example, if males have a different probability of being in a sample than females, then the covariate gender would capture this effect. In addition, foreign undocumented drug users have no access to low threshold
methadone treatment. Including this subgroup would violate the homogeneity assumption, and thus produce overestimation. For this reason, as mentioned before, the only user room for this segment of the crack using population was excluded from the study.

3. Closed population: no addition or subtraction of cases during the observed period. This assumption can be violated by individuals starting or stopping their use, leaving the city, incarceration, hospitalization, or death. We minimized the violation of this assumption by establishing a six-month period for inclusion (March 2009–August 2009 for Amsterdam, December 2009–May 2010 for The Hague, and August 2010–January 2011 for Rotterdam, adding up to an overall study period of almost two years). In addition to the exclusion of foreign undocumented crack users for violation of the homogeneity assumption, this group was also excluded because it constitutes a floating population and its members are encouraged to leave the country in a short time.

4. Independence of samples: the probability of appearing in one sample should be statistically independent from appearing in another. By using a three-source approach, the interaction effects between each combination of two samples can be adjusted, assuming that there is no three-source interaction (Bishop, Fienberg, & Holland, 1975).

3.2.1. Data analysis

We used log-linear modelling to estimate the number of current crack users by city (‘Amsterdam,’ ‘Rotterdam,’ and ‘The Hague’); age group (‘younger than 35 years’ and ‘35 years and older’); and gender (‘male’ and ‘female’). This way we were able to test if the effects for age and gender are the same for the three cities, making it possible to reduce the number of parameters, and also reducing the fluctuation due to smaller samples per city. The best model was selected according to the BIC, and this model provided the estimate of the number of people who did not appear in any of the samples. The parametric bootstrap was used to generate 95% confidence intervals.

3.4. RESULTS

Table 1 shows the number of subjects matched in each data source by city, gender, and age. A total of 2,417 unique individuals were included in at least one of the samples: 1,026 (42.4%) in Amsterdam, 982 (40.6%) in Rotterdam, and 409 (16.9%) in The Hague. In total, 342 subjects (14.1%) appeared in two data sources and 50 (2.1%) in all three data sources. Overall, 20.6% were female, ranging from 22.3% in substitution to 12.6% in user rooms. The percentage of those aged younger than 35 years was 9.4%, and ranged from 7.7% in user rooms to 12.6% in RDS. The following model was selected: [US][URG][UC]

[SC][SA][GA][AC], where U is user rooms, S is substitution, R is RDS, G is gender, C is city, and A is age group. The best fitting model included positive interactions between user rooms and substitution and between user rooms and RDS, in the latter case especially for females (OR 5.46 vs. 2.22 for males). Crack users aged 35 years and older were likely to attend substitution, to be male, and to live in Amsterdam or Rotterdam. The model also showed
Table 1. Number of crack dependent users on data sources by covariate.

<table>
<thead>
<tr>
<th>City</th>
<th>Gender</th>
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<td></td>
<td>Male</td>
<td>Female</td>
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<td>&lt;35</td>
<td>≥35</td>
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<td>Amsterdam</td>
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<td>Yes</td>
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<td>1</td>
<td>2</td>
<td>2</td>
<td>15</td>
<td>15</td>
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<tr>
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<td>50</td>
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<tr>
<td></td>
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<td>No</td>
<td>22</td>
<td>468</td>
<td>14</td>
<td>118</td>
<td>622</td>
<td>604</td>
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<td>Rotterdam</td>
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<td>10</td>
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<td>1</td>
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<td>No</td>
<td>9</td>
<td>91</td>
<td>2</td>
<td>9</td>
<td>111</td>
<td>98</td>
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<tr>
<td>The Hague</td>
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<td>Yes</td>
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<td>73</td>
<td>3</td>
<td>33</td>
<td>116</td>
<td>115</td>
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<td>Yes</td>
<td>1</td>
<td>10</td>
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<td>1</td>
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<td></td>
<td>1764</td>
<td>546</td>
<td>549</td>
<td>44</td>
<td>774</td>
<td>24</td>
<td>184</td>
<td>1026</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>22.4%</td>
<td>12.6%</td>
<td>20.8%</td>
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<tr>
<td></td>
<td>&lt; 35 years</td>
<td>7.7%</td>
<td>9.9%</td>
<td>12.6%</td>
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<tr>
<td></td>
<td>Amsterdam</td>
<td>44.6%</td>
<td>41.0%</td>
<td>37.7%</td>
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<tr>
<td></td>
<td>Rotterdam</td>
<td>42.9%</td>
<td>40.5%</td>
<td>35.5%</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>The Hague</td>
<td>12.5%</td>
<td>16.5%</td>
<td>14.0%</td>
<td></td>
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</tr>
</tbody>
</table>

S=Substitution treatment, U= User rooms, R=Respondent-driven sample (RDS).
interactions between city and user room, and city and substitution, with crack users from The Hague having a lower probability of appearing in these samples.

Estimates of the total population by city, gender, and age are given in Table 2. The number of unobserved crack dependent users was estimated at 4,242 in the three cities altogether, providing an overall estimate of 6,659 (95% CI: 5,891–7,761), from which 2,524 (95% CI: 2,185–2,977) were estimated to be in Amsterdam, 2,362 (95% CI: 2,032–2,766) in Rotterdam, and 1,773 (95% CI: 1,463–2,172) in The Hague. The prevalence of crack dependence for the population aged 15–64 years is therefore estimated at 0.46% (95% CI: 0.40–0.54) for Amsterdam in 2009, 0.58% (95% CI: 0.50–0.68) for Rotterdam in 2010, and 0.53% (95% CI: 0.44–0.65) for The Hague in 2010. The estimated percentage of females was 23.0%, with no significant difference across the three cities. The estimated percentage of those younger than 35 was 12.8%, with more crack users in this group in The Hague (21.8%) than in Amsterdam (8.4%) and Rotterdam (10.8%).

Table 2. C-RC estimates of the crack dependent population and prevalence by city, gender, and age.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Observed</th>
<th>Estimate (95% CI)</th>
<th>% of population 15-64 (95% CI)</th>
<th>% of total estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amsterdam</td>
<td>1,026</td>
<td>2,524 (2,185-2,977)</td>
<td>0.46 (0.40-0.54)</td>
<td>37.9</td>
</tr>
<tr>
<td>Rotterdam</td>
<td>982</td>
<td>2,362 (2,032-2,766)</td>
<td>0.58 (0.50-0.68)</td>
<td>35.5</td>
</tr>
<tr>
<td>The Hague</td>
<td>409</td>
<td>1,773 (1,463-2,172)</td>
<td>0.53 (0.44-0.65)</td>
<td>26.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Observed</th>
<th>Estimate (95% CI)</th>
<th>% of population 15-64 (95% CI)</th>
<th>% of total estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1,919</td>
<td>5,128 (4,530-5,970)</td>
<td>0.79 (0.70-0.92)</td>
<td>77.0</td>
</tr>
<tr>
<td>Female</td>
<td>498</td>
<td>1,531 (1,286-1,839)</td>
<td>0.24 (0.20-0.28)</td>
<td>23.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Observed</th>
<th>Estimate (95% CI)</th>
<th>% of population 15-64 (95% CI)</th>
<th>% of total estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;35</td>
<td>226</td>
<td>825 (673-1,069)</td>
<td>0.15 (0.12-0.19)</td>
<td>12.8</td>
</tr>
<tr>
<td>≥35</td>
<td>2,191</td>
<td>5,804 (5,144-6,703)</td>
<td>0.78 (0.69-0.90)</td>
<td>87.2</td>
</tr>
<tr>
<td>Total</td>
<td>2,417</td>
<td>6,659 (5,891-7,761)</td>
<td>0.51 (0.46-0.60)</td>
<td>100</td>
</tr>
</tbody>
</table>

### 3.5. DISCUSSION

We used three-source C-RC to estimate the number of crack dependent users in the three largest Dutch cities (Amsterdam, Rotterdam, and The Hague). The same types of data sources were used for each city: an RDS survey and two institutional data sources (user rooms and low threshold opiate substitution treatment). RDS was applied to reduce potential sampling biases in the user survey (Heckathorn, 2002). User rooms and opiate substitution treatment were chosen because, unlike in other commonly used sources (e.g., police, prison, or emergency room data), crack use is consistently registered. According to Smit et al. (2006), between 70% and 90% of opiate users in the Netherlands are also crack...
users, which makes substitution treatment lists very adequate for the purpose of this study. In the case of user rooms, almost the totality of their visitors use crack. Other sources like specialized treatment for crack addiction are less numerous (because, contrary to opiates, there is no medical substitute for crack) and often patients are not current users. Although obtaining a normative sample of the population is not possible in this case because there is no population frame from which it can be drawn, the three types of samples chosen were the best available for our purpose.

The accuracy of C-RC, like all indirect estimates, depends on the extent to which the underlying assumptions are met. In the method section, four assumptions were defined: (1) the assumption of perfect matching was not problematic since substitution institutions and user rooms register their clients in similar ways, and respondents in RDS were asked for their ID. Individual identification and matches were carefully checked to avoid mistakes; (2) the homogeneity assumption can be violated because drug users represent a heterogeneous population and may not have the same probability of being captured. Part of this variability was controlled for by the inclusion of covariates (city, age group, and gender) in the analysis and the exclusion of undocumented foreign crack users; (3) the closed population assumption was addressed by establishing a restricted time window of six months for each city. Undocumented foreign crack users were also excluded because they only stay for a short period in the city. Consequently, our estimates only refer to the population of crack dependent users with stable residence (including homeless) in these cities; and (4) to address the last assumption (independence of samples), all data was aggregated for log-linear analysis.

The selected model indicated interactions between the user room and opiate substitution samples. This might be explained by the fact that both are low threshold facilities that collaborate with each other, and user rooms can refer clients to an opiate substitution program, and vice versa. However, this does not explain why RDS and user room samples also showed dependency. Our model took these interactions into account, resulting in a crack dependence estimate of 6,659 (95% CI: 5,891–7,761) for the three cities: 2,524 (95% CI: 2,185–2,977) in Amsterdam, 2,362 (95% CI: 2,032–2,766) in Rotterdam, and 1,773 (95% CI: 1,463–2,172) in The Hague, providing prevalence rate of 0.51% (95% CI 0.46–0.60) for the population aged 15–64 years. This rate was lowest for Amsterdam (0.46%; 95% CI: 0.40–0.54) and highest for Rotterdam (0.58%; 95% CI: 0.50–0.68), although all three prevalence rates had overlapping confidence intervals.

Our estimates are much lower than in London, where Hope et al. (2005) estimated the prevalence of crack users aged 15–44 years at 1.5% (95% CI: 1.0%–3.2%). How could this difference with Dutch cities be explained? Firstly, RDS in our study might have generated more representative user samples than the convenience sample in London, but this cannot explain an overestimation on their side, since a more representative sample could include even more subjects who are not observed in institutional settings and therefore raise the estimations. Secondly, the British researchers applied a wider definition of their target population (crack use vs. crack dependence in our study) and a wider time window (one year vs. six months). Thirdly, the age range was much narrower in the London study than in ours, and more than half were younger than 30, while in our study most crack users (60.8%) were older than 44 and the estimated percentage of those younger than 35 was 12.8%. This age
difference is in line with other studies, indicating that crack use might be a problem of more concern in London and is also more prevalent among the younger generation than in Dutch cities (Eisenbach-Stangl & Moskalewicz, 2009; Van der Poel & Van de Mheen, 2006).

The crack dependent population in these Dutch cities is mainly middle-aged and male, with females representing less than one-fourth (23.0%). This distribution is similar to those of the London study (22.4%) and our substitution sample (22.4%), but higher than for patients with cocaine as their primary problem in the national registration system (17%; Ouwehand et al., 2010) and for those in our user rooms sample (12.6%). Also, crack users younger than 35 years were underrepresented in the drug services samples (7.7% in substitution and 9.9% in user rooms vs. 12.8% estimated). This suggests that drug user treatment services might be having less success in reaching female and younger crack users. It also indicates that estimates based on institutional data alone will be less valid for female and younger crack users. Therefore, it appears adequate to include a non-institutional sample (like RDS in this case) in C-RC estimations in order to obtain more reliable estimates of the target population.

**Declaration of interest**

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