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EMCDDA SCIENTIFIC REPORT

Macro-economic analysis of heroin markets in the EU and the impact of substitution treatment

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Table of Contents

Executive summary

Introduction

Approximately 2 to 7 per 1000 people in the European Union are problematic users of opiates. This is a major concern to policy makers and therefore different measures are frequently proposed or under investigation. Currently, little information is available to provide a complete picture of the past, current, and expected future demand for heroin in different stages of addiction. Yet, such information would allow the analysis/simulation of the possible impact of different preventive and repressive measures to restrain heroin use and addiction.

Objectives

The objective of this study was therefore to develop a macro-economic model, simulating the career of potential heroin users and the accompanying demand for heroin. Additionally, the effects of different measures and changes in the settings of available substitution treatment were the subject of analysis. The secondary goal of this study was to identify the gaps in information, and consequently indicate the nature of data needed in future research.

Methodology

Based on the available literature and reports, the existing economic behaviour theories and different modalities of people using heroin were identified and discussed. These discussions provided a number of principles, but most of all a thinking-framework and background for the creation of a macro-economic model at a cohort level.

Practically, this was done by applying the methodology of a Markov state transition model, within which a (potential) cohort of heroin consumers makes transitions from one "state" to another within discrete time frames (here set at 6 months). The states presented in the model were: "non-user", "has sampled", "(non-dependent) user", "ex-user", "dependent-not treated", "dependent-treated with methadone+other drug-intake", "dependent-treated with methadone", "abstinent", and "death". The model starts with a theoretical population of >12 year-olds (all non heroin users). After 10 years, a cross-sectional population may be obtained and broken down into different 'states'.

Individual's choices within the heroin market and the quantity of heroin consumed depend on consumer's budgetary constraints (income and heroin price) and the price of other drugs (substitutes and complements).

The model was fed with estimated values on transition probabilities between different 'states' and economic factors (price and income elasticity). However, information on the *dynamics* of heroin use and substitution is scarce and, when available, mostly applies to non-EU populations. The challenge in the coming years will be to obtain such data from field studies carried out in the EU.

By calculating the model for a chosen time horizon of 20 years, an average demanded quantity of grams of heroin could be determined at a cohort level. Sensitivity and scenario analyses then showed consecutively the impact of variations in different parameters and the effects of different measures on the model results. By using a bottom-up approach, the basecase results at an individual level may be aggregated to model the heroin demand at the population level. Finally, mainly in order to take into account inter-country variability in heroin use, a number of additional analyses were performed.

After 10 years, the effect of changes in heroin price, income level, access to substitution treatment and incidence of persons experimenting with the drug was modelled and the impact on heroin demand over the next 10 years was assessed.

Results

Calculating the 20-year demand for heroin at cohort level generated an average demand estimate of between 5.96 to 20.45 grams per person, depending on different factors. On a European population level (>12 years), the estimated demand was between 1,920,000 and 6,595,000 kilograms (street purity) over 20 years.

Different measures were introduced in the model at year 10 and their effect on the cumulative heroin demand was modelled. The largest impact was observed when modelling changes in heroin price levels: according to the model developed, a 50% increase in the price level could have a negative impact of 72% on total heroin demand. Also the prevention of trying heroin could be a potentially effective measure: a decrease of sampling with 50% would generate an almost equal impact on total heroin demand.
Modelling the impact of substitution treatment indicated that an easier access to treatment would have a larger impact than the success of treatment itself in attaining abstinence.
The possible reactions of the supply side, that is the possible effect of a decreased demand on price and supply, were modelled as well, but these seem to have little effect on the relative performance of the different proposed measures.

The model started with a closed cohort of non-users > 12 years old. At year 10, it is estimated that the population is cross-sectional according to the current situation in Europe regarding the different 'states' considered in the model. In the model used, it would imply a total 1-year demand between year 10 and 11 at the population level between 61,300 and 170,900 kilograms (street purity). These results are highly dependent on the value attributed to several parameters, and the range is especially due to taking into account a variation in heroin price.

Discussion

Developing a macro-economic model for heroin use was a challenging task. Many gaps were discovered in available information and a number of assumptions had to be made. Particularly, several parameter values had to be estimated, based on expert opinions. Other parameter values were often necessarily derived from scientific literature involving small samples, specific selected populations, and mostly North-American studies. This should be taken into account, since these data were also used for generalisation of results and extrapolation in an European model. In addition, several assumptions should be tested with more extensive and up-to-date European data.

However, we believe that the current model gives some interesting indications of what might be the relative impact of different measures on the overall demand for heroin. Thus according to the model, measures focusing on prevention of trying heroin could have a large impact on heroin demand, while strategies targeting an increase in the heroin price, would seem to have a larger impact. Any conclusions such as these, need to be tested much more thoroughly, however, using more adequate European data.

1. Introduction and objectives

The aim of this study is to examine the demand for heroin at different stages of addiction, and develop thereto a macro-economic model, simulating the career of a potential heroin user. Additionally, the effects of different measures and changes in the settings of available substitution treatment were subject of analysis. The secondary goal of this study was to identify the gaps of information, and consequently indicate the nature of data needed in future research.

Currently available information on heroin use is mostly oriented towards epidemiological data and some isolated health economic results of substitution treatment.
However, straightforward and directly applicable information on the *dynamics* of heroin use and substitution is poorly available for the EU.

The availability of substitution treatment is also in economic terms a “substitute” for the “product” heroin, and has as such an influence on the demand curve for heroin.

The exact substitution rate from heroin to substitution treatment will depend on several factors:

- Factors related to the individual
- Factors related to the individual’s environment
- Factors related to the competing products (heroin, methadone, and others) and the way they are supplied

It is clear that these factors interact and that the isolated effect of one factor may be different from the effect of that factor within a larger group of factors. Also, some factors can be influenced by intervention, while others cannot.

Because successful policies are associated with clear objectives regarding expected outcomes; the EMCDDA decided to outsource the development of an economic model of heroin market behaviour and hence, after aggregation, heroin markets.
Once validated, such a model will allow to predict the possible effects of substitution treatment on price, consumption, supply of heroin and other aspects of the heroin market within the EU. The model should also enable to predict the relative impact of different interventions, such as for instance law enforcement, vouchers, etc…

This project is a common effort of Modus Vivendi, HEDM and Dr. Juan Tecco, with the help of experts in the field, Mr. Steve Parrott (UK), and Dr. Nacer Lalam (France)

2. Methodological steps

Step 1. Description of the economic behaviour on a cohort level

The following tasks were performed:

1. Literature search and review, both socio-medical literature as economic literature. Available sources: Medline, Embase, HEED (health economic evaluation database), Social Sciences Citation Index.
2. Quantitative data selection from the available literature
3. Draft macro-economic model, consisting of source variables (external variables), and intermediate variables (i.e. variables that can be influenced by the external variables). No single variable will be considered as permanent internal variables, that is, each variable is assumed able to influence other variables (see further). The model was designed as a state transition model, simulating the "career" of a heroin addict. The transitions from one "state" to another are dependent on the set of source variables and intermediate variables.

The model was then populated with values for the different variables and transitions.

In the literature, a quite important quantity of information is available with regard to the individual's choices within the heroin market. The heroine market is a set of arrangements by which buyers and sellers are in contact to exchange heroin. The essential features of such a market are demand and supply.

The quantity of heroin demanded depends on four elements:

- its own price,
- the consumer's income,
- the consumer's "utility profile" and
- the price of and access to related goods (substitutes and complements).

Utility is defined in economics as the value of a function that represents a preference ordering of different combinations of goods and services consumed (Gafni and Birch, 95). The utility function differs among people and is unique for each person. If, for instance, someone prefers chocolates over apples, this is explained by his/her utility function.

Obviously, the consumer's income and the prices at which products (here drugs) can be bought define the consumers budget *constrains*. The budget constraint shows the maximum affordable quantity of one good given the quantity of another good being purchased. Hence, the budget constrains summarise the market environment (income and prices) of the consumer. In the heroin market, along their budget line, heroin users can only obtain more heroin by sacrificing consumption of other goods.

Now, as time goes by, heroin consumers experience unwanted effects and complications related to heroin consumption. The subjective perception of the price paid to consume heroine changes, which has an *income* and a *substitution* effect. For instance an income effect of a price increase is

to reduce the quantity demanded of heroin as well as the quantity of other goods. The substitution effect, induced by relative price movements, leads consumers to substitute away from the good whose relative price has increased, and to replace it by other goods.

From the above it is clear that demand for heroin can be modified by changes of budget constrains. There is evidence for instance that the price of heroin has dropped to 60% of its price 10 years ago and that the quantity of heroin demanded increases as its price drops (Handreas 1997).

The available literature on the above described market mechanisms was fully explored and reviewed within this project, focussing not only on qualitative descriptions such as above, but focussing on all available *quantitative* information.

Step 2. Aggregation to a population-level model

The macro-economic model on the cohort level was aggregated to a population-level model. The aggregation is vertical, that is, the individual demands, as predicted by the known levels of the explaining variables in the model, are cumulated to predict a population demand.
In other words, by using a bottom-up approach, the sum of all “individual/cohort markets” is obtained.

Step 3. Validation of the macro-economic model

The model predictions were compared with data from epidemiological surveys and other observational or retrospective data.
The epidemiological data were obtained from literature and from contacts with experts from a reference group and other centres.
The following example shows how the validation works: the model predicts, based on its complex bottom-up structure, that an increase in supply of substitution treatment, will result in an x% reduction of the heroin demand, given a certain level of the other variables. From published data obtained from a setting, which corresponds with the model settings on that moment, the “real” effect can be compared with the predicted effect. If differences occur, it can be explored by which variables these differences are explained.
This validation is a repetitive process, until the model is validated by the available epidemiological data.

In the next paragraphs, an overview of the literature is provided, focussing first on the general economic theory of addiction, shaping the framework and direction of thinking. The next chapter describes the concrete application the principle of that economic thinking, namely the model, simulating the “career” of a possible heroin user. That model was completed with data, obtained from the available literature, and a full description of the logic for application of these data into the model was given within the same chapter. However, the model presents a general evolution, applicable to a whole population, consisting of a mix of different types of people, for whom

different probabilities may account for. Therefore, in order to be complete, a number of factors that may influence the evolution of a person throughout the model are discussed in a subsequent chapter.

Finding the right data to populate the model often appeared to be not so evident. However, in case no readily useful data were found, an attempt was made to make an estimate in an as justifiable way as possible.

3. Specific features of heroin addiction

Heroin is a potent reinforcer with significant abuse potential. However, not everyone who tries heroin continues using heroin or develops debilitating addiction. The underlying factors responsible for individual differences in the probability of becoming addicted and in the response to treatment of the addiction can be broadly categorised into three classes of factors: factors related to the individual, environmental-based factors, and treatment-related factors. These three classes should not be seen as separate entities explaining why or why not a person becomes addicted or why substitution treatment has more effect on one person compared to another. At least to a certain extent, variables of different classes are intuitively expected to interact and/or to influence one another, either directly or indirectly.

3.1. Individual susceptibility

Interpersonal differences in susceptibility to opiates may lie in genetic differences, gender differences, difference in ethnic origin, and whether or not a psychiatric co-morbidity is present.

3.1.1. Genetic differences

A goal of genetic research of behaviour is to identify the relative proportion of variability due to genetic and environmental factors. Although there is evidence of genetic differences among individuals who are drug users, the role of specific genetic differences remains controversial. Moreover, how differences in genetic structure translate into behavioural risk is still unknown (Elmer et al, 98). Therefore, the genetic aspect is currently not to be considered in behavioural models.

3.1.2. Gender differences

Existing research has highlighted gender as an important factor in drug using activities, help seeking behaviour and service centre experience. This is described in detail below.

3.1.2.1. Epidemiological data

Apparently, studies analysing gender differences among drug users are scarce. About one third of clients enrolled in Methadone Maintenance Treatment (MMT) in the US are female, but that number is increasing (Chatham et al, 1999).

Two possible explanations may be given for this gender difference in utilisation rate of drug services. First, these figures may suggest that fewer women use drugs, but this kind of interpretation should be made with caution. Indeed, the fact that men outnumber women by a three

to one ratio as client of services could be reflecting the fact that female drug users are less likely than their male counterparts to present to drug services (Down, 1994).

This controversy is still unresolved. Literature reports that services are often inappropriate to women's needs and societal norms, which makes it difficult for women to present to drug treatment services. Indeed, the level of service provision specifically assigned to meet the needs of women remains low, and services often fail to provide specific services for female clients and child care facilities. In contrast, Hunter and Judd (1998) identified surprisingly high levels of contact with a range of specialist and generic health services in relation with drug use among female intravenous drug users in London. Four fifths of the sample had been in contact with a health service, over a half with a drug service and nearly half with both in the preceding 6 month. Only 14% of respondents reported no contact in that period. The most common reason for no contact was that they had no need (83.3%).

In any event, it is very important to identify gender differences in admission characteristics and treatment outcomes. Epidemiological research in people on MMT found gender differences for a number of factors. Among males, for instance, an excess prevalence of *personality disorders* was found versus females. Women, on the other hand, showed a higher prevalence of *mood disorders*, *borderline personality disorder* and consistently entered MMT at an *earlier age*. Fewer females than males completed high school although this difference was not significant. Females were less frequently employed, were more likely to receive public assistance and reported fewer arrests Hunter and Judd (1998).

In a US study by Wechsberg et al. (1994), females reported more *financial* and medical problems than males. They were hospitalised twice as much (not including childbirth) as their male counterparts, and had more respiratory and mental problems like anxiety, emotional dysfunction and two times more depressive episodes.

In another US report, females appeared six times more likely to be the victim of physical and sexual abuse than males. Their environment while growing up was significantly more pathological as evidenced by maternal abuse, parental criminality, and parental treatment for mental illness and substance misuse. More specifically, they were more likely to have had relatives with substance misuse problems than males (De Jesus et al., 1997). An unclear discrepancy was found regarding HIV/AIDS risk behaviour. Females entering MMT have safer needle use behaviours but are more likely to exchange sex for drugs or money, although they report using condoms more consistently than males.

A survey, performed by the INSERM and the INVS (Institut National de Veille Sanitaire) for the OFDT in 2673 attendees of needle exchange centers in France (Emmanuelli et al., 1999) found no differences in the proportion of males and females who underwent substitution treatment.

The paucity of outcome studies addressing gender differences in clients enrolled in MMT makes a review challenging. When engaged in MMT, both genders show significant improvements from admission to follow up in terms of reduced drug use and criminal activity. In some areas, like family relationships and psychosocial status, women seem to benefit more from treatment than men.

The key differences between Male and Female addicts are listed in the table below:

Gender	Male	Female
Age		Enter MMT at an earlier age
Resources	More frequently employed	More public assistance
Criminality		Fewer arrests
Medical problems		Hospitalised more (2x)
Mental problems	Excessive prevalence of personality disorders	More anxiety, emotional dysfunction and depressive episodes (2x), borderline personality disorder (7x)
Personal history		More physical or sexual abuse (6x), more "pathological family environment"
HIV/AIDS risky behaviour	Riskier sexual and needle use behaviours	Exchange sex for money or drugs

3.1.2.2. Patterns of consumption

Patterns of consumption of addictive goods differ between men and women. Females were found to drink less alcohol (but this could be related to body weight) and use less marijuana than males. More females smoked over a pack of cigarettes a day and reported significantly more respiratory problems. Also tranquillisers, sedatives and stimulants were used more frequently by females. Contradictory results were reported regarding the use of heroin and cocaine, although this could be due to an evolution in the consumption pattern of the latter. Early studies found females to use less cocaine than males, while recent studies show that more females than males combine cocaine with opioid use. (Chatham et al., 1999; Bretteville-Jensen, 1999).

Studies in the US and Panama by Van Etten et al. (1999) illustrate additionally that male-female differences in the prevalence of illicit drug use could be traced back to male-female differences in the occurrence of initial opportunities to use these drugs, and not to the differential likelihood of making the transition to use, once an opportunity was presented. The proportion who was offered at least one **opportunity** for using drugs was **7.8% for males and 3.2% for females ($p<0.001$)**. A difference in making the transition to **first use within one year once an opportunity occurred** was observed (14.6% for men versus 22.1% for women) but was statistically not significant (p ranged from 0.11 to 0.54 across investigated drugs).

The figures of Van Etten et al. (1999) and Emmanuelli et al. (1999) provide justification that differences between males and females can be brought down to differences in opportunities to try heroin. The fact of having more opportunities of trying heroin is expected to be reflected directly in the number of men and women trying heroin! Therefore, in the model, to analyse differences between men and women, the differences in sampling will be our calculation tool.

However, in order to test the effect of the hypothesis of difference between men and women being true, the above figures will be applied in the model and discussed as a subanalysis.

3.1.3. Ethnic origin

There has been an increasing effort to probe the meaning of differences in the prevalence of drug use for groups varying by demographic characteristics such as race and ethnicity. In 1988 and 1990 NHSDA, lifetime prevalence rates for crack use were over twice as high among African Americans and Hispanic Americans compared to White Americans. However, because neighbourhood characteristics may promote the use of drugs, conflicting explanations for these differences have been proposed. Two analyses that controlled for neighbourhood of residence thereby holding constant shared characteristics such as drug availability and social conditions found that the odds of crack use did not differ by race or ethnicity (Chilcoat and Schutz, 1995). So, in conclusion, most studies show differences (minorities use more drugs) but when environmental factors are controlled, differences seem to disappear.

3.1.4. Psychiatric co-morbidity

The American Psychiatric Association (APA) developed a classification of mental health disorders, the DSM IV (APA, 1994), which provides diagnostic criteria for use in research studies. The DSM IV identifies two types of psychiatric disorders. The "Axis I disorders" are psychiatric disorders with a more discernible onset and variation, such as depression, psychosis or anxiety. A personality disorder is a so-called "Axis II disorder" if it is an enduring, relatively constant condition (as in the case with a mental handicap). Major studies of psychiatric comorbidity among opioid misusers reported that about 80% of patients met the criteria for at least one non-substance use related psychiatric disorder, with rates of mood disorders and Anti Social Personality Disorders (ASPD) that far exceed general population estimates (Regier et al, 90). The positive associations between psychiatric comorbidity and the severity of substance use and other psychosocial problems is most consistent among those with ASPD (Seivewright and Daly, 1997).

3.1.4.1. Axis I disorders

Brooner et al. (1997) documented the psychiatric and substance use-related co-morbidities among MMT-seeking opioid users. Lifetime prevalence rates were 24% and *current rates* were 8%. Apparently, there are gender-specific differences in diagnostic prevalence rates of Axis I disorders.

Women seemed more likely than men to have a non-substance Axis I diagnosis with a lifetime *prevalence* of 33.4% versus 15.6%, and *current rates* of 11.2% versus 5%, for women and men respectively. These figures seem very conservative when compared to previous studies (Rousanville et al., 1982) and may be associated with variations in population and methods. For example, lifetime mood disorders in earlier studies ranged from 60 to more than 70%, while Brooner 's rate of mood disorders was only 19%. Note, however, that in Brooner et al. diagnostic evaluations were made 3 to 4 weeks after admission. An assessment, performed after a therapeutic intervention is considered conservative when it is compared to measurements during the admission process, which is a time associated with increased symptom reporting.

3.1.4.2. Personality disorders or Axis II disorders

A key feature of personality disorders is that the personality pattern that is formed by adolescence of early adult age, is characteristic across different situations, and is maladaptive in that it leads to significant impairment in social, occupational or interpersonal functioning.

The DSM IV groups the personality disorders into three clusters. Cluster A is the odd, eccentric cluster. Cluster B is the dramatic, emotional and erratic cluster and includes the histrionic, narcissistic, *antisocial* (ASPD) and borderline personality disorders. Cluster C is the anxious, fearful cluster. Most findings in drug users concentrate on cluster B disorders DSM IV (APA).

The available evidence suggests that approximately two thirds of opiate users in treatment have personality disorders. The antisocial personality disorder (ASPD) is the most common followed by other cluster B disorders (Seivewright and Daly, 1997). Five studies using conventional DSM diagnosis found rates of ASPD between 35% and 59% (Skodol et al., 1999). Methodological variations can explain these differences, in particular the great difficulty in separating personality disorders from drug use behaviours.

DSM IV diagnostic criteria for ASPD include a pattern of behaviour since the age of 15, as indicated by at least four of the following:

1) Failure to conform to social norms with respect to lawful behaviours as indicated by repeatedly performing acts that are grounds of arrest.
2) Deceitfulness (Lying, conning the other for personal profit or pleasure)
3) *Impulsively or failure to plan ahead*
4) Irritability and aggressiveness (repeated fights or assaults)
5) Reckless disregard for safety
6) Irresponsibility (work, financial obligation)
7) Lack of remorse

More specifically, the main features of ASPD include criminality, aggressiveness and impulsiveness, but in the case of drug users the pitfalls are obvious: disinhibition, reckless

behaviour resulting from direct effects of drugs; irritability and aggressiveness from withdrawal; and acquisitive crime developing purely to procure drugs.

Note that prevalence rates, as detected in clinical treatment settings cannot be considered necessarily representative of drug users in general. The lifetime prevalence of ASPD in drug users in the community was found to be 17.8% (Regier et al, 1990). *In the general population, the prevalence of ASPD is 3% among men and 1% among women* (Kaplan et al., 1990)

Personality disorders have been found to be associated with a range of complications and adverse outcomes in drug use. They might lead to more severe or prolonged drug use. Moreover, in case of ASPD-related medical and social complications, an increased HIV risk behaviour and infection rates (18% in ASPD versus 8% in NON ASPD) (Seivewright and Daly, 1997), more legal problems, poorer social functioning and more current crime are observed. Borderline personality disorders has been more frequently associated to women.

Studies investigating the progress of drug users in a therapeutic MMT setting show that clients with ASPD have greater heroin dependence and are less responsive to therapy for additional cocaine use. Also dropouts from outpatient treatment are more frequent (Seivewright and Daly, 1997).

Alterman et al. (1998) examined the correlations between the presence of ASP and methadone treatment outcomes. A statistically significant negative correlation was found between the presence of ASPD and treatment completion (-0.2) and a positive correlation between ASPD and opiates use while in treatment (0.137). These figures will be used in order to run the model for a subgroup of people with ASPD.

This study group's opinion is that ASPD subjects could fit the non-rational economic behaviour model (see further). The non-rational model implies that myopic, compulsive behaviour is by construction the cause of addiction.

3.2. Environmental factors

Two major categories of environmental factors might have causal impact on drug use among adolescents and young adults: contextual and interpersonal (Hawkins et al, 1992). Contextual factors include risk factors in the broad social context, such as laws and norms affecting drug-using behaviour, extreme economic deterioration and neighbourhood deterioration. Although contextual factors may not be very malleable, they nonetheless can provide important clues for successful intervention approaches. Three interpersonal factors on which researchers focussed much attention are family, peers and school/occupation. Countervailing influences such as access to alternatives to drugs and risk factors such as stress or previous history of drug use can be both contextual or/and interpersonal.

3.2.1. Contextual factors

The importance of the environment, and the related necessary controls in designs studying ethnic susceptibility, was underlined earlier in this document.
Restricting access to drugs decreases consumption. A pilot study by Yanagita (1973) demonstrated breaking points at which rhesus monkey ceased efforts required to obtain drugs.
The implications for these findings for prevention of human drug use can be extrapolated up to certain limits. The ability to increase the difficulty of obtaining drugs in a democratic society might be limited.
Two studies examined whether the children's perception of their neighbourhood environment may signal a greater risk for using drugs and for drug sampling (= trying a drug for the first time) (Crum et al., 1996; Schultz et al., 1993). The results indicate that children in the higher tertile of neighbourhood disadvantage were most likely to report past exposure opportunities for using drugs and drug sampling.

3.2.2. Interpersonal factors

Animal research using cocaine self administration has provided some indications of the type of environmental factors that can decrease drug using behaviour and thus be considered countervailing influences. Punishment (Electric shock) to be more effective must be consistent and immediate (Azarin, 1966). In that sense, when extrapolated to human observations, proximal parent control seems potentially more suited (consistent and immediate) than the judicial system.
Two studies by Chilcoat et al., 1995 and 1996, examined the hypothesis that parent monitoring could have an important impact on children's drug behaviour. Their findings suggest that parent monitoring blocks the transition to drug use even for children who are likely to have been exposed to opportunities to use drugs.

In adult studies, the importance of the drug users network has been emphasised. Willems et al. (1997) found that intravenous drug users networks might be reduced during MMT.

Azalos et al. (1999) revealed the importance of the association between the daily living situation and program completion. Of those patients in a stable living situation, without substance abusers present, or those who transitioned to that situation, more than 60% (34 of 45) completed a 6-month program. Of those living with a substance abuser, only 1 of 11 patients (9%) completed the 6 months of treatment.

3.3. Factors related to treatment

Patient retention of addictive substances is an important goal for MMT. Magura et al. (1998) identified predictors of retention in MMT for a sample of 1206 admissions to 15 clinics in New York.

Although pre-treatment variables like older age and no criminal justice involvement were associated with longer retention, the authors suggest that events during treatment are crucial for patient retention in MMT. Five of six during-treatment variables had significant effects on the length of stay in a multivariate model. More specifically, clinic constructive response to patient problems (medical, physical, social drug related and non- compliance events), higher methadone dosage, more patient treatment strengths (motivation for change) and less heroin and cocaine use during treatment were all positively related with success of treatment.

3.3.1. Pre-treatment and early treatment Factors

This group of treatment related factors are in fact factors related to the individual and/or the environment. We discuss them here since in the literature they are often categorised as treatment related factors.

Up till now, research has uncovered few demographic and other pre-treatment factors that reliably predict performance in substance abuse treatments (Morral et al., 1999). Among these few, *younger age, greater severity of drug use and psychiatric problems* seem to be the most consistent predictors of poor outcome. Note however that the latter is not in line with the findings of Saxon et al. (1994) who found that the severity of drug use and psychiatric problems account for only a small fraction of outcome variance, and are not consistently related to outcomes.

Several studies show that, the older the patient at admission of MMT, the longer the length of stay (Ball and Ross, 1991; Brown et al., 1983). It may be that older patients are more likely to have cumulated negative consequences of an addict lifestyle and are more mature in a psychological sense. For example, ASPD has been systematically associated with opioid use and general findings from epidemiological research include a decreasing rate on ASPD with age (Tyrer et al., 1988).

Controversially, justice involvement has been linked both positively (Grella et al., 1994) and negatively to retention. Interestingly, gender, ethnicity, employment, education, marital status, living arrangements, child care responsibility, lifetime arrests, referral source, age at first use of heroin, poly-drug use, route of administration, mental health status and MMT history were not linked with treatment retention.

Some authors suggest that it might be possible to predict MMT response based on drug use in the days immediately preceding treatment admission (Morral et al., 1999; Alterman et al., 1997; Morral et al., 1997; Budney et al., 1995) and counselling attendance during the first two weeks.

3.3.2. In-treatment environment

3.3.2.1. Reinforcers

Drug use often initiates as a consequence of various factors *or reinforcers* such as peer pressure or medical circumstances, in a situation in which drug is available. Subsequent drug use serves as a reinforcer to maintain and strengthen drug seeking and taking.

Drug self administration could be modified by a range of environment variables that affect behaviours. These include the schedule and magnitude of reinforcement and the reinforcement of alternative incompatible responses like reinforcement of abstinence. Under these procedures, drug using patients receive desirable and tangible consequences, contingent on providing objective evidence of abstinence (like urine samples).

Under this intervention, patients receive immediate benefits such as more flexibility, as taking home methadone doses, vouchers, housing or salary for work for providing drug-free urine samples (Silverman et al., 1999; Milby et al., 1996; Azalos et al., 1999). Interestingly, in the case of vouchers, more than drug-free urine samples, treatment plan-related tasks (be on time, make an appointment…) for vouchers seem generate a significant improvement in abstinence rates over time and even after the intervention was discontinued (Igushi et al., 1997).

Tasks targeted towards *long term goals* increase the involvement in behaviours that are inconsistent with drug use among MMT clients. In that case, participants are brought into contact with reinforcers occurring naturally in their environment that maintain changes in behaviour after removing the experimental contingencies (Kidorf et al., 1998).

The importance of psychosocial treatments in the context of methadone maintenance treatment was impressively demonstrated in a 24-week trial by McLean et al. (1993). Ninety-two opiate addicts were randomly assigned to receive either (1°) MMT alone, (2°) MMT with standard psychosocial services, including regular meetings with a counsellor, or (3°) enhanced MMT including regular counselling and on-site medical, psychiatric, family and employment therapy. The best outcomes were seen in the enhanced MMT group, intermediate with standard psychosocial services and the worst outcomes with MMT alone. 69% had to be transferred from condition 1 to one of the 2 others within 3 month because their substance misuse did not improve or worsened. The authors conclude that MMT alone may be sufficient for a small group, the majority however, would benefit more from higher levels of psychosocial interventions.

3.3.2.2. Decreasing response requirements

Alternatives incompatible to drug use (free urine samples, employment, social rehabilitation…) can be promoted or "reinforced" with benefits. Equivalently "decreasing response requirements", seeks to reduce the cost of adopting those alternatives.

Some operant research suggests that decreasing response requirement is functionally equal to increasing reinforcement magnitude (Bickel et al., 1990). Studies indicate that for a population of severely, multiply dependent, and otherwise not ill substance users, treatment outcomes are improved when treatment is accessible (Greenfeld, 1996) and when admission is rapid (Maddux, 1995). Decreased requirements have been described to be of particular benefit for clients with social anxiety (Avants et al., 1998).

There appears to be a clear link between attitudinal factors and service provision (Matheson et al., 1999). Increased remuneration for service provision and further training may promote more positive attitudes among healthcare service providers for drug users *and thus decrease response requirements.*.

3.4. Summary

The following tables provide an overview of the possible factors influencing heroin use. In the model, we withheld gender and psychiatric co-morbidities as major influencing factors (see also further).

1. Individual susceptibility

1.1. Genetic differences.	How differences translate into behavioural risk is still unknown.	
1.2. Gender differences	Male	Female.
Population enrolled in MMT	2/3	1/3
Age		Enter MMT at an earlier age.
Resources	More frequently employed.	More public assistance.
Criminality		Fewer arrests.
Medical problems		Hospitalised more (2x).
Mental problems	Excessive prevalence of personality disorders.	More anxiety, emotional dysfunction and depressive episodes (2x), borderline personality disorder (7x).
Personal history		More physical or sexual abuse (6x), more "pathological family environment".
HIV/AIDS risky behaviour	Riskier sexual and needle use behaviours.	Exchange sex for money or drugs.
Patterns of consumption	Drink more alcohol (but could be related to weight). Use more marijuana.	Use more tranquillisers, sedatives and stimulants. Smoke more cigarettes.
1.3.Ethnic origin	No differences when the environment is controlled.	

1.4.Psychiatric comorbidity	80% at least one non substance psychiatric disorder (most frequently ASPD and mood disorder).
Axis I (mood disorder among MMT seekers 3 to 4 weeks after admission)	Life time prevalence 24%. Current rate 8%.
Axis II (ASPD)	Primary 35%, Secondary 59% among MMT seekers (2% among general population, 7.8% in the community). Severity of substance use is most consistent among those with ASPD. Greater heroin dependence and less responsive to therapy.

2. Environmental factors

2.1.Contextual factors	Neighbourhood environment signal greater risk.
2.2.Interpersonal factors	Parental monitoring reduces drug use. During MMT, IV drug users networks are reduced. Program completion is associated with stable living situation, without substance abusers present

3. Factors related to treatment

3.1.Pre-treatment	Small fraction of outcome variance. Older age is associated with longer retention
3.2.Early treatment	Drug use in the days immediately preceding treatment admission and counseling **is associated with negative outcome** Attendance during the first two weeks **is associated favorable outcome**
3.3.In-treatment (Response requirements/ reinforcers ratio)	Reinforcement of abstinence (short term: vouchers; long term: acting on environmental factors through psychosocial interventions) **are positively associated with treatment outcome** Decrease response requirements (accessible treatment, attitudes of service providers and rapid admission) **have been described to be beneficial**

4. Economic theory of addictive behaviour

4.1. A History of theories

According to a review by P. Kopp, it appears that in the early seventies, the first authors who were interested in the behavioural economics of drugs considered the demand for drugs to be *inelastic* to the price level, that is no matter the price of heroin, the consumption will not be affected by this price. It was hence generally believed that the level of delinquency of the drug addict was altered in function of the price changes of drugs. Thus, an addict was believed to search different paths in order to obtain the necessary revenues for purchase of a desired quantity of drugs.

A number of original researches were consecutively performed to test these theories.

Hadreas and Roumasset (1977) found in their research that the daily consumption of drugs in heroin addicts was larger than the quantity they really "needed". They launched the idea of a possible *elasticity* of the demand towards the price. They developed a model where elasticity and inelasticity of the demand were combined according to the capacity of the addicts to restrain their non-addictive consumption in order to meet the price increase of heroin.

Brown and Silverman (1974) and Silverman and Spruill (1977) were the first to actually measure elasticity. By using an extensive statistical database, they found that the demand of heroin depended on the purity of the drug and the price during the previous months. In the long term, the demand varied very little with the purity of the drug, but more to changes in price levels: *a price-elasticity of -0.25 was found, that is, for a 1% increase in price, the consumption decreases by 0.25%.*

Other authors claimed that the sensitivity of drug consumers did not only depend on *changes* in the price, but also from the *existing price* level before any augmentation. In other words, the elasticity is not a constant figure. Blair and Vogel (1973) suggested an elastic demand at low prices and inelasticity as prices raised. Hence, the absolute value of elasticity was decreasing with increasing price and the demand curve was said to be convex. White and Lusksetich (1983) contested this point and claimed the opposite (a concave demand curve). The latter authors also stressed the existence of a strong substitution between heroin and other drugs, as availability of heroin decreased and/or its prices increased.

Later in the eighties, a theory of *rational addiction* was developed by Becker and Murphy (1988), who stressed a difference between long and short-term price elasticities. This rational theory stands opposite to the myopic theory, as described, amongst others, by Winston (1980). The two approaches yield entirely different characterisations of the addictive process. In the rational approach, individuals *choose* to risk addiction and hence attain an optimal outcome, which optimises their utility. In the non-rational setting, addiction arises from a compulsive act, which would raise short term individual welfare. The non-rational model implies thus that myopic, compulsive behaviour is by construction the cause of addiction. An important implication of this is that even rehabilitated addicts may remain equally impulsive and myopic, and therefore susceptible to relapse (Orphanides and Zervos, 1998). Myopic behaviour would also be related to lower elasticity.

A problem with the rational approach was that it has been hindered by the incompatibility of the theory with one of the defining aspects of addictive behaviour, namely the possible variability in the addicts' *difficulty in delaying gratification* and his/her *disregard for the future*. In other words, the rational theory indicated that the individual time preference (i.e. the preference of current above future joy) is fixed (Bretteville-Jensen, 1999) . Literature today tends to adopt the rational theory, but with a less binding assumption of time preferences, often expressed by the hypothesis that as *the past consumption of the addictive good increases, the rate of time preference increases as well*. Past consumption consequently induces myopia (Bretteville-Jensen, 1999; Orphanides and Zervos, 1998). This approach will also be adopted for the elaboration of our model.
The next paragraph discusses these aspects more in detail from a rather complex theoretical perspective. The paragraph aims at detailing the theoretical economic fundamentals of addictive behaviour. Later, the clinical and epidemiological and thus practical implications of this behaviour will be outlined. The latter will be of more importance to our model.

4.2. The theory of rational addiction

The current section is based on several references describing and commenting the theory of rational addiction (Bretteville-Jensen, 1999; Becker and Murphy, 1988; Becker, 1991; Grossman and Chaloupka, 1998). In their theory, Becker and Murphy (1988) assume that people maximise the total discounted (= actualised to the present) value of utility over their life span, subject to a budget constraint. The solution of this maximisation problem leads to the deduction of behavioural equations, indicating how optimal decisions of individuals depend on certain parameters, e.g. on the prices of the goods. Moreover, these behavioural equations will be subject to certain restrictions. If T equals the length of life and σ (sigma) a constant rate of time preference, the utility function in the theory of rational addiction would be:

$$U(t) = \int_0^T e^{-\sigma t} u[y(t), c(t), S(t)]dt$$

Where
U(t) is the discounted lifetime utility (discounted to a present value at the time preference rate σ);
u [..] is the period-specific utility;
y(t) is the consumption of non-addictive goods;
c(t) is the consumption of addictive goods;
and S(t) is the stock of 'addictive' capital, building up over time

The stock, i.e. the addictive capital S(t) is a function of previous consumption of addictive goods and life events. It can be considered as the built up effect of past consumption. On the other hand, it also depreciated at a rate δ per year. The depreciation indicates the waning effect of the stock: consumption of 3 years ago has a much lower influence than consumption yesterday.

The two central features of addictive behaviour, *tolerance* and *reinforcement,* are defined in terms of the addictive capital stock,:

Tolerance means that addictions are harmful in the sense that the utility of a given level of consumption today becomes lower the more of the addictive good the individual has consumed earlier ($u_s = \partial u/\partial S < 0$). Stated differently, the larger the stock the lower the additional utility of a fixed amount of present consumption. Hence, in order to obtain more utility, more consumption is needed than before.

Reinforcement means that, all other variables being constant, greater past consumption of addictive goods *increases the desire* for present consumption. In other words, the marginal utility of increased consumption today increases the more the individual has previously consumed ($u_{cs} = \partial^2 u/\partial c \partial S > 0$). In other words, a larger need is satisfied. Moreover, for the rational utility maximiser (who also considers possible consequences of future behaviour) reinforcement requires that the marginal utility of c(t) exceeds the negative effect of higher S(t).

Mathematically, it can be demonstrated (via complex mathematical derivations) that a necessary and sufficient condition for reinforcement near a steady state (where c=δS, thus where current consumption is equal to the depreciation of the stock) is:

$$(\sigma + 2\delta)u_{cs} > -u_{ss}$$

where: - u_{cs} is the marginal utility of c(t) following a change in S(t), and
- u_{ss} is the marginal utility of S(t), obtained from a change in S(t).

The value of $u_{ss} < 0$, since this represents the adverse consequences of drug addiction (a negative utility). The above formula was obtained through a number of steps that are described in more detail in Becker and Murphy (1988).

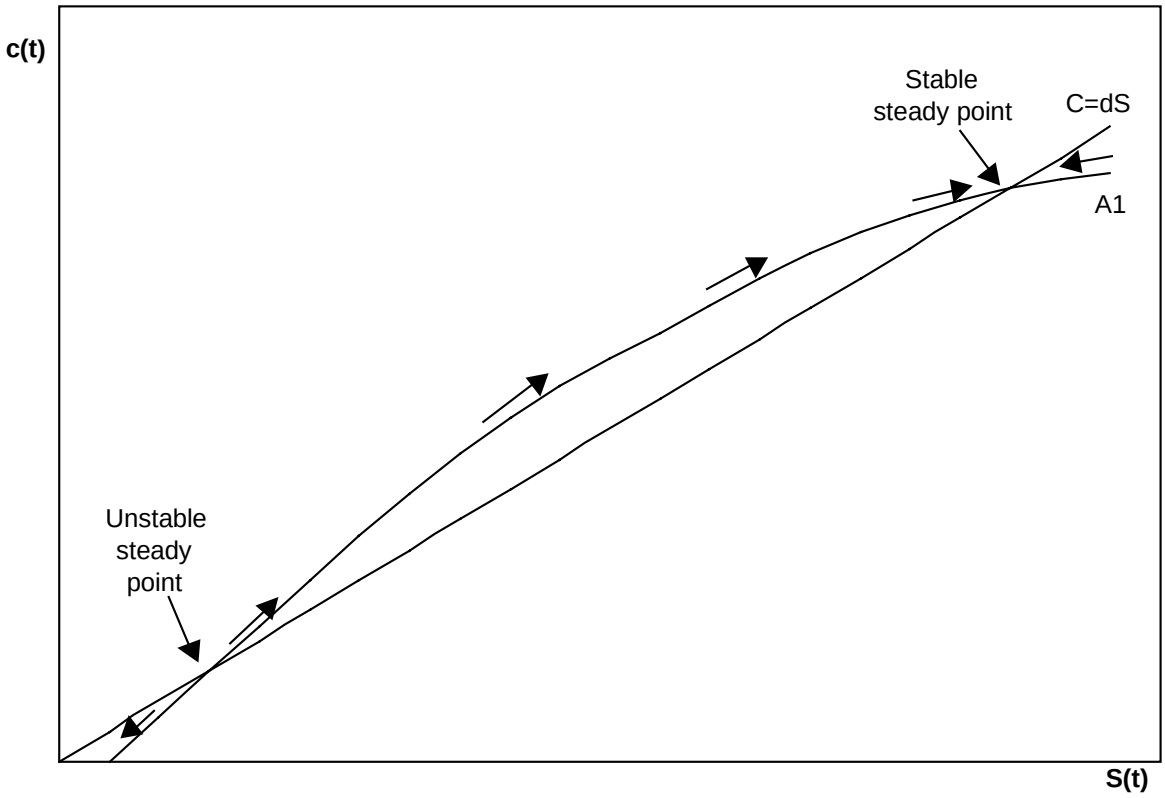
Practically, and in simple terms, the above equation means that S(t) and c(t) are positively correlated: the more past consumption, the more present consumption.

If we take a step back and consider the practical implications of the above theory, reinforcement as summarised in the above equation has the important practical implication *that the consumption of addictive goods at different times are complements*. Therefore, an increase in either past or expected future prices decreases current consumption. The relation between these effects of past and future prices depends on both the time preference and the depreciation rate of stock.
This brings us to the individual characteristics. The theory of rational behaviour claims that *addiction is more likely for people with high preferences for the presence (high σ) and for those whose stock of consumption capital depreciates more rapidly (high δ).*

The demand of an individual who has a particular utility function, under given prices and wealth is in the theory represented by a positively sloped demand curve (see figure 1; A_1). The curve is positively sloped since the more stock, the more consumption. The positive slope is however decreasing, since Ucs > 0. Summarised, the more stock, the more consumption is needed, but the increments in needed consumption decrease ("you need more, but not so much more anymore")
All combinations of c and S for which there is a steady state (equilibrium) may be represented by the linear curve $c=\delta S$. Practically, and as mentioned before, a steady state means that current consumption of addictive goods compensates precisely for the depreciation ('loss of effect') of past consumption of addictive goods (e.g. S = 100, $\delta = 0.05 \rightarrow c = 5$).

Points where the demand curve for c cuts the steady state line represent steady state points. The theory emphasizes that multiple points of equilibrium on the demand curve are central to the theory. This means that the same person may have different levels of consumption at different times, even though economic factors confronting the individual are the same.

Figure 1: demand for drugs in function of past consumption



Knowing the above and taking the discussed features of addictive behaviour into account implies that addicts *respond more to permanent* than to temporary changes in prices of addictive goods. Indeed, suppose the consumer is at the stable steady state point (upper right). A sudden price increase may drop the consumption, but given the Stock level (which cannot decrease as suddenly), the consumer will show a *consumption directed again towards the stable steady point*. This is indicated by the direction of the arrows on the above graph. Only in case of permanent price changes, there is sufficient time for the Stock to depreciate, and the reduced consumption may be a fact.

The degree of addiction is stronger when A^1 is steeper, and *long run* responses to price changes are then also greater! Strong addictions do consequently not imply weak long term price elasticities.

Kopp states that the theory of Becker and Murphy only applies to people who are really addicted to drugs, and less or not to occasional drug users. Since the "true" addicts are the selected population according to the objectives of the current analysis, it is justified to adopt the principles of the rational addiction model for our model.

4.3. Comments/adaptations to the rational addiction model.

4.3.1. Discount rate

A central aspect in the theory of rational addiction was the discount rate (σ), which was said to be constant over time. The importance of people's discounting as a contributory factor in explaining addiction has also been emphasized by others. The Ainslie (1992) theory of intertemporal choices differs from the Becker-Murphy theory in basically two points: in the form of the discount function and in the notion of the fixed discount rate. The shape of Ainslie's temporal discount function is hyperbolic rather than exponential: discounting would be steeper at short delays of availability of the addictive good, and additional equal increments of delay produce progressively less additional discounting. Moreover, the relative value of two alternatives available at fixed times can switch, based solely on the addition or subtraction of an equal delay to both alternatives. Given thus the form of the discount function, an alternative that was inferior from a distance may become preferred when its availability becomes immediate. Hyperbolic discounting leads consequently to regular and systematic inconsistencies and changes in preferences (Monterosso and Ainslie, 1999).

According to Monterosso and Ainslie (1999), the following formula is fit to represent the hyperbolic discounting:

$$v_d = \frac{V}{(1+kd)}$$

In which:

v_d : the present discounted value of a delayed reward;
V: the objective value of the delayed reward;
k: an empirically derived constant proportional to the degree of discounting (i.e. sensitivity to the delay); and
d: the delay duration.

Thus the larger the delay, the smaller the present value.
Note that the *kd* in the above formula was represented by the sign σ in the discussion of the Becker and Murphy-theory in the previous section.

Bretteville-Jensen (1999) tested the assumptions about time-preferences of Becker and Murphy empirically on the basis of estimates derived from three groups of people with different consumption levels of illegal intoxicants. Results seemed to confirm the interpersonal variability of discount rates between people with different experiences of addiction to an addictive substance. *Moreover, active users had a significantly higher discount rate than non-users, which is in line with the high time preference rate as a contributory cause.*

The assumption of stable time preferences, however, was not confirmed by the results. The theory of rational addiction *namely does not consider the possibility that addictive behaviour itself may change an individual's time preference*. Bretteville-Jensen states that a high discount rate may be one among several causes of addiction, but also that great impatience and *shortsightedness* will probably also arise as a result of addiction.

This greater impatience arising from addiction seems to be confirmed in a paper of Becker and Mulligan (1997), although the point of departure there was a given, excessively high time preference for each person. Rational people would then lower the size of their time preference to a varying extent, by responding to different incentives to invest in future-oriented capital. Bretteville-Jensen did find neither confirmation nor rejection of the assumption of stable preferences with their results, but plead for an approach in which this assumption is less binding.

Bretteville-Jensen additionally found that empirical discount rates do not only consist of a 'pure' time preference, as reported in the theory of rational addiction. Empirical rates would also be influenced by other factors, such as the individual's income and wealth, their life expectancy, and the extent of uncertainty and risk involved:

$kd = f_i(\sigma_j, \pi_j)$

In which:

kd: the estimated discount rate for person j (same as kd in the previous formula)

σ_j: the 'pure' time preference rate representing individual j's balancing of utility in different periods; and

π_j: a rate vector of all the other factors.

4.3.2. More goods

Pacula (1997) presents a general model of substance use that allows for the possibility of multi-commodity habit formation (2 commodities in this paper). The application of that model would lie in the analysis of the intertemporal relationship between the consumption of legal and illicit drugs, or the "gateway effect". The model of Pacula builds on the framework of the theory of rational addiction, with two important differences. First, tastes are allowed to change with prior consumption of either drug. Second, the focus of the theoretical implications is on the multi-commodity case.

The consumption capital stock variable (S(t)) in the Pacula-model represents the cumulative influence of past consumptions of both drugs (legal and illicit). The single capital stock has important implications for the model because past consumption of one substance can then influence the marginal utility of consuming the other.

As in the theory of rational addiction, in case of multi-commodity habit formation, due to reinforcement, the marginal consumption of a new drug is higher, ceteris paribus, when there is past consumption of the other drug. Next to that, the individual will initiate drug consumption with that drug that has the lowest marginal cost. Finally, the particular sequencing of drugs can be explained by differences in the marginal cost of consuming particular drugs.

The mathematics of the model remain basically the same as in the Becker and Murphy model, except for the fact that the variables of all considered commodities are included in the utility function and the reinforcement condition.

4.4. Empirical applications

As discussed in the introduction of this report, various variables (may) have an influence on the substance-abusing behaviour of a person. A number of economic authors have tested empirically the influence of (changes in) these variables. Results were found on two broad classes of variables:
(1) Environmental constraints on access to the abused substance; and
(2) Alternative, (nonsubstance-related) activity opportunities and the constraints on access to them.

4.4.1. Research on environmental variables influencing access to the abused substance

According to Vuchinich and Tucker (1998) extensive research has repeatedly demonstrated an inverse relation between substance use and abuse and direct constraints on access to the substance. Examples of such direct constraints are changes in price and availability of the drug. Petry and Bickel (1998) analysed in this respect the changes in drug choices as a function of price and money available.

Three experiments were performed in patients following an outpatient program for opioid abuse and dependence. Patients were given an imaginary income, and were to allocate that money under different circumstances. In a first experiment, the price of heroin was changed while all other variables remained constant. The effect of these price changes on purchase patterns of heroin, Valium®, cocaine, marijuana, and alcohol was examined.

Other aspects that involve the user's environment are other drugs than heroin. The relative price of these drugs versus the price of heroin may be determining for the user's choice for heroin or other substances. Thereto, a second experiment examined the effects of changes in both heroin and Valium® prices on purchases of these drugs (income remained constant). Experiment 3 examined the effects of increasing income on drug choices, with drug prices constant.

As the price of heroin rose in experiment 1, heroin purchases decreased. Reductions in heroin purchases were proportionally less than price increases, demonstrating inelastic demand for heroin. More specifically, when heroin doubled in price from 3$ to 6$ per bag, over 85% of subjects

showed inelastic demand for heroin but, as price increased to 11$ and $35, demand for heroin became more elastic ($p<0.0001$). In other words, at higher prices, the demand is more elastic. Valium® ($p<0.0001$) and cocaine purchases ($p<0.0001$) increased as heroin price rose, and cross-price elasticity coefficients indicated that *these drugs substituted for heroin* (see table 1). However, in the case of cocaine, this was only true for 23% of the subjects. The purchases of alcohol and marijuana did not differ significantly with changing heroin prices.

In experiment 2, both demand for heroin and Valium® was inelastic. Valium® substituted for heroin: over 60% of subjects substituted Valium® for heroin as heroin prices increased (see also Table 1; Experiment 2a). In contrast, *heroin purchases were independent of* Valium® *prices: cross-elasticity values for heroin versus the price changes of* Valium® *were very small*, ranging from 0 to –0.047 (see also Table 1; Experiment 2b). Marijuana and alcohol purchases were independent of Valium® price, but both these drugs substituted for heroin ($p<0.05$) (see Table 1).

The third experiment showed that the demand for heroin and cocaine was income elastic, with purchases rising in greater proportions than income ($p<0.0001$). Marijuana, alcohol and Valium® purchases did almost not vary with income, demonstrating that the demand for these drugs was income inelastic (see Table 1).

Table 1: Own price-elasticities, cross-price-elasticities and income elasticities (experiment 3) for different drugs in changing environmental conditions for these drugs. Coloured areas present own price-elasticities. Cross-elasticities are calculated towards the drug with the coloured area (Source: Petry & Bickel, 1998).

	Heroin	Valium®	Cocaine	Marijuana	Alcohol
Experiment 1					
Heroin price from 3$ to 35 $; Ceteris Paribus	-1.042	1.056	0.822	0.464	0.451
Experiment 2a					
Heroin price from 3$ to 35 $; Valium® price 0.33$	-1.088	1.024	*	0.819	0.780
Heroin price from 3$ to 35 $; Valium® price 1$	-1.064	0.990	*	0.746	0.403
Heroin price from 3$ to 35 $; Valium® price 3$	-1.064	0.990	*	0.746	0.403
Heroin price from 3$ to 35 $; Valium® price 10$	-1.054	0.929	*	0.797	0.594
Experiment 2b					
Valium® price from 0.33$ to 10$; Heroin price 3$	-0.013	-0.944	*	0.300	0.061
Valium® price from 0.33$ to 10$; Heroin price 6$	-0.011	-0.809	*	-0.059	0.032
Valium® price from 0.33$ to 10$; Heroin price 11$	-0.002	-1.055	*	0.154	0.165
Valium® price from 0.33$ to 10$; Heroin price 35$	**	-0.962	*	0.020	-0.094
Experiment 3					
Income from 30$ to 560$	1.038	-0.004	0.708	0.152	0.370

*Not reported by the authors since too few subjects purchased cocaine, or their demand was independent of heroin price.

** The price of heroin exceeds the available income here, so that no heroin can be purchased here.

Bretteville-Jensen (1999) examined differences in consumption and economic behaviour among male and female heroin addicts (n=1834) through interviews in a needle exchange service. She found that the consumption pattern of the heroin addicts varies by gender, with females consuming relatively more heroin, but less alcohol and cannabis than their male counterparts. By means of a switching regression model, price and income elasticities for both genders were estimated. Next to differences between genders, separate analyses were performed for heroin dealers (47% of the investigated population) versus non-dealers. As a result, women appear to be more price-responsive than men, and non-dealers are more price-responsive than dealers. Non-dealing males seem to have a higher income elasticity than non-dealing females, whereas in the dealing subpopulation the opposite was observed.

Whether or not a heroin user becomes also a heroin dealer is considered a matter of choice by Bretteville-Jensen. Moreover, due to the dealers' role as both user and supplier, their more readily access to drugs, better knowledge of product quality, and their ability to purchase on credit, different price and income elasticities were expected for dealers versus non-dealers. Therefore, consumption equations of dealers and non-dealers were expected to differ in this analysis.

The results of Bretteville-Jensen (1999) are quite different compared to Petry and Bickel (1998), and are presented in table 2. The table shows for each regression variable the corresponding coefficients, which represent the elasticities of each variable to the demand for heroin.

Table 2: Elasticities of the demand for heroin for changes in different parameters as calculated by Bretteville-Jensen (1999).

	Male (n=901)	Female (n=469)	Both genders (n=1370)
Dealer's consumption			
Intercept	28.0	-21.2	7.75
Age	0.85	0.38	0.18
$Price^{HEROIN}$	-0.36	-0.35	-0.41
$Price^{OTHERDRUGS}$	-3.05	2.18	-0.81
Income	0.59	0.83	0.69
Non-dealer's consumption			
Intercept	-13.9	-6.65	-14.1
Age	0.19	-0.07	0.06
$Price^{HEROIN}$	-1.51	-1.90	-1.61
$Price^{OTHERDRUGS}$	2.23	1.88	2.17
Income	0.51	0.36	0.60

Brettevilde-Jensen (1999) took the price of other drugs into account by inclusion of a price index of the Laspeyres type. This means that the evolution of prices of a certain basket of goods (here cannabis, amphetamines and Rohypnol®) is taken into account in the model by means of an index (see formula below). The index is calculated by calculating the relative price change of that basket of goods versus a base year.

$$\text{Laspeyres-Index} = \frac{\sum (P_n / P_0)(P_0 Q_0)}{\sum P_0 Q_0} * 100$$

where P_n: current price; P_0: base price; P_0Q_0: base year weight.

The figures of Bretteville-Jensen (1999) will be used in our model. The figures relate to a much larger population compared to the study population of Petry and Bickel (40 subjects). However, few details are provided about specific cross-price elasticities of heroin towards other drugs. For that particular item, data of Petry and Bickel (1998) will be cited.

The key data we will keep in mind for application in the model are:

- The –1.61 own price-elasticity of the demand for heroin addicts (Bretteville-Jensen, 1999),
- The 0.60 income elasticity of the demand for heroin addicts (Bretteville-Jensen, 1999),
- The fact that heroin purchases were independent of Valium® prices (Petry and Bickel, 1998).

No quantitative data were found on the impact of prices of other possible substitutes (eg. alcohol, other opiates) on the demand for heroin.

In our economic model we will build in the possibility of substituting other drugs for heroin. Unfortunately, no data were available on how cocaine prices affect the demand for heroin, and no data were found on this topic in other sources. However, the elasticity of the demand for cocaine versus price changes of heroin was estimated at 0.82 by Petry and Bickel (1998). A comparative study performed by Craig and Olson (1990) in the US, however, showed that the similarities in personality between heroin and cocaine addicts were greater than their differences. Moreover, Hasin et al. (1988) showed that, while dependence indicators differed markedly between regular and sporadic users of these drugs, cocaine dependence indicators did not differ from heroin dependence indicators. Therefore, we will assume that the cross-elasticity works in both ways, so that the elasticity of the demand for heroin towards price changes of cocaine among addicts is set at 0.82 (see further).

4.4.2. Research on access to alternative, nonsubstance-related activity opportunities.

As described by Vuchinich and Tucker (1998), from the choice perspective, addictive behaviour patterns emerge, develop, and change over time within temporally extended environmental contexts. These contexts are characterized by stability and change in access to drug and nondrug-related activity opportunities. This “molar” view is consistent with two general and important features of addictive behaviours.

First, addictive behaviours typically *exhibit variability over time* that is not well represented by a "snapshot" of behaviour at one particular time. The course of addictive behaviours, including development, stability, recovery, and relapse, is *apparent only over lengthy time periods*.

Second, the molar context of other activity opportunities that surrounds addictive behaviour patterns is likewise conceived from a broad temporal perspective. Such a temporally extended context is necessary to represent the complex life circumstances within which addictive behaviour problems are embedded and strongly influence their development and change.

Apparently, within this molar context, a direct relation between drug use and constraints on access to nondrug alternative activities was found. This class of variables emphasizes concepts of impulsiveness and self-control. *Impulsive choice* can be defined as the choice for a smaller, but less delayed reinforcer/reward over the choice of a larger, more delayed reinforcer/reward. The self-control principle is then the opposite (Hyten et al., 1994).

Under natural conditions, drug availability is typically minimally constrained and constant relative to the considerable variability in access to valued nondrug alternatives. Vuchinich and Tucker (1998) *therefore believe that the access to nondrug alternatives rather than drug availability may better explain drug-taking patterns in natural environments*. Moreover, the authors believe that constraining drug access or increasing the price of drugs without also providing alternative activities usually intensifies drug-seeking behaviour and any associated criminal activity.

4.4.3. Research on discount rates.

An important variable encompassing the concepts of impulsiveness and self-control is the discount rate of the drug user. As described extensively in earlier sections, immediate substance use apparently is positively correlated with the individual's rate of discounting.
In general, an individual's demand for a "sooner small reward" (drug use; impulsiveness) versus a "later larger reward" (valuable alternative activities; self-control) can be represented as a function of delay interval. That is, as the delay to reward delivery is increased, the subjective value of that reward, and the capacity of the delayed reward to motivate behaviour, is decreased (Madden et al., 1997).

Technically, the subjective value of delayed rewards may be represented by indifference curves. That is, to determine the point of indifference between immediate and delayed rewards, the values of the immediate and delayed rewards are adjusted until the preference for both rewards is equivalent. When indifference points are determined across a range of delays, an indifference curve may be plotted that provides information about the rate at which the subjective value of a reward decreases with increasing delays of reward delivery.

Madden et al. (1997) investigated delay discounting in opioid-dependent and non-drug using control participants. In both groups, participants chose between hypothetical rewards. Delayed rewards were 1000$, and the immediate reward was adjusted until choices reflected indifference. This procedure was repeated for 7 delays (varying between 1 week to 25 years). Opioid-dependent participants were given a second series of choices between immediate and delayed heroin, using the same procedures (i.e.; the amount of delayed heroin was that which could be purchased with 1000$). It appeared that opioid-dependent participants discounted delayed monetary rewards significantly more than did non-drug-using participants. Moreover, opioid-dependent participants discounted delayed heroin significantly more than delayed money (see Table 3).

Table 3: Parameter estimates, Interquartile range, and average R^2 values derived from opioid-dependent and control groups' median delay discounting functions (Madden et al., 1997).

Group	Condition	N	Median estimated discounting rate (*k*)	Interquartile range	Average R^2
Opioid	Heroin	18	***4.17***	1.00-9.40	0.80
Opioid	Money	18	0.22[a]	0.06-0.58	0.95
Control	Money	38	0.03[b]	0.02-0.07	0.99

[a] $p<0.001$ compared to heroin in opioid-dependent participants; [b] $p=0.01$ compared to opioid-dependent participants.

The median estimated discounting rate (k) in the above table is an indicator of the sensitivity of a (group of) person(s) towards a given delay. It is the rate at which the subjective value of monetary rewards decreased with increasing delays. It is a constant, proportional to the degree of discounting, and is multiplied by 'd', the delay duration, in order to obtain the discount rate per given period of time. The interquartile range shows the 25^{th} and 75^{th} percentile for the observed k within each patient group. The R^2 gives an indication of the correlation between increasing the estimated discount rates and impulsivity, as measured by the Eysenck Impulsivity Scale scores.

In order to empirically test the hypotheses of the theory of rational addiction, Bretteville-Jensen (1999) estimated annual discount rates for three different groups: non-misusers, ex-misusers, and active injecting addicts (see Table 4). All were clients of the needle-exchange bus in Oslo.

Table 4: Average annual discount rate and corresponding discount factor for active users, non-misusers, and ex-misusers of hard narcotic substances (SD in parentheses).

	Sample size	Annual discount rate (kd)	Annual discount factor (1/(1+kd))
Active users	110	0.90 (1.77)	0.53
Non-misusers	110	0.05 (0.13)	0.95
Ex-misusers	50	0.15 (0.24)	0.87

The annual discount factor is the factor by which the objective value of a delayed reward is multiplied in order to know its present value. The definition of the annual discount rate is explained above.

A great difference is observed here between the rates of active and former misusers, which does not seem to accord with the theory of Becker and Murphy of stable time preferences. A high discounting rate is said to be a contributory cause of drug misuse. According to the theory, consumption capital will be reduced when consumption of addictive goods diminishes, but the actual discounting ought to remain unchanged. Consequently, one would expect ex-misusers also to have a high value on their discount rate. The fact that ex-misusers show a higher discount rate, proves that at least to a given extent impulsiveness is not only a consequence of addiction, but that some addicts are impulsive "by nature". We come back to this issue later.

Notes with this chapter

Note 1:
The economic theory of addiction, as described in this chapter served especially as a thinking frame in which the model was to be created. Some empiric results served moreover as relevant data input into our model. Many formulas, principles and items described are not directly applicable/retraceable in the lay-out/programming of our model. However, should we have opted for another approach than the modified rational addiction theory, our model would not look the same as it does now.

Note 2
The concept of discount rate cannot be retraced literally in the programming of our model (see next chapter). The discount rate is embedded in the concept of time related elasticity, which is used directly in the demand function. The elasticity of a person's demand for heroin towards a certain variable, like the price of heroin, gives an indication of the sensitivity of the demand towards changes in price levels of heroin. According to the theory of rational addiction, an economic agent (=heroin consumer) will decrease his demand as prices go up. A person with a high discount rate, therefore, who is consequently very shortsighted, will react less rationally towards a price increase. This means that his demand will not decrease proportionally as much as the proportion of the price increase. By definition, this person's demand for heroin shows a low elasticity towards the heroin price.

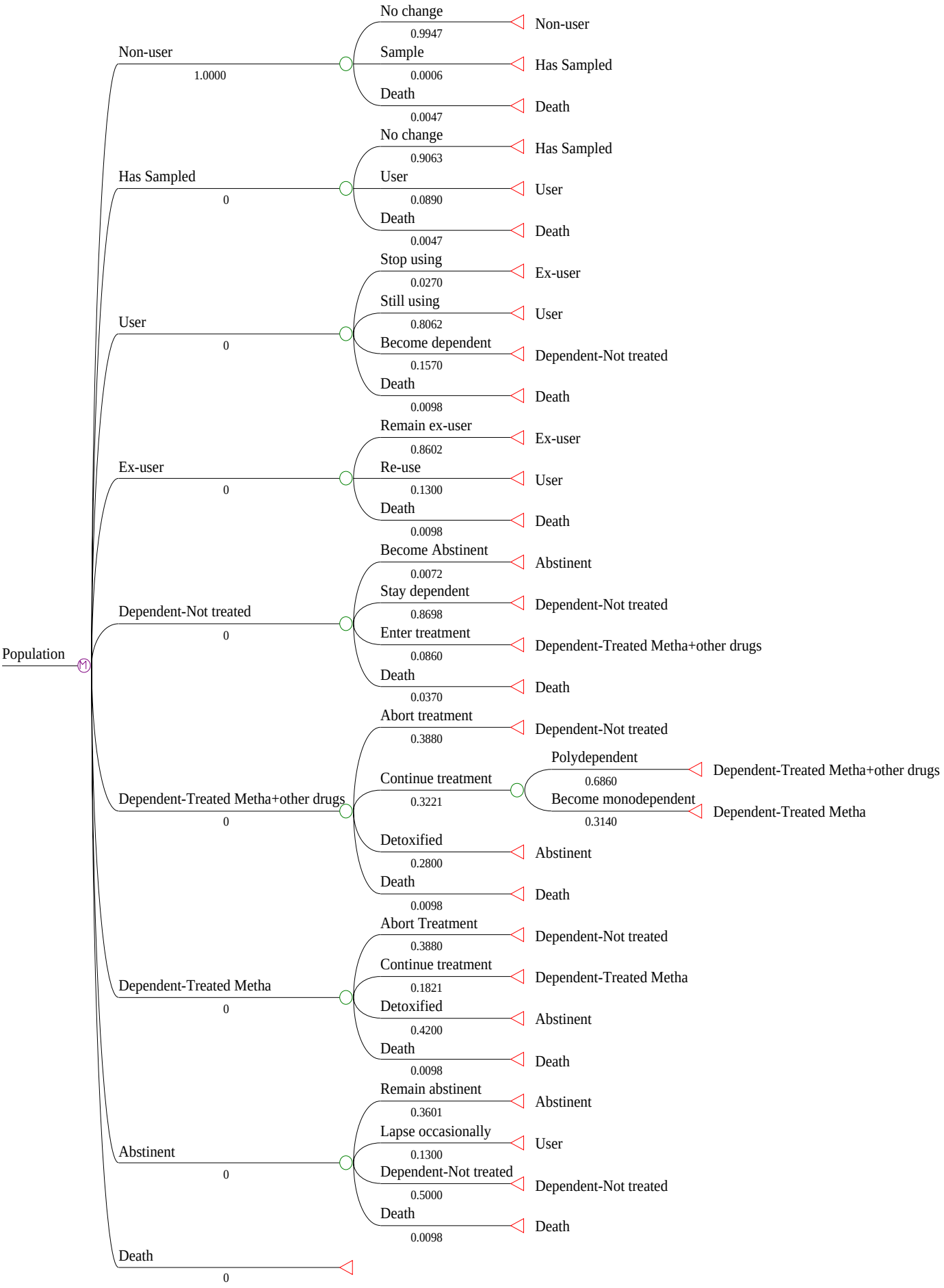
5. The economic model

5.1. The economic model: Markov state transition

A Markov model was developed to simulate the career of a possible heroin user. Based on such a model, the impact of interventions, changes etc.. on behaviour can be simulated.
The Markov state transition model is based on mutually exclusive "states", in which a person can remain at a given point in time. At any time, all persons starting in the model must be in any of these states. A second feature of a Markov model is the "stage", also called the "cycle", i.e. a fixed period of time, e.g. 6 months. After every of these discrete time periods the cohort in the model can either move through the model from one state to another or alternatively stay in the same state. In general it is assumed that the transitions happen on average in the middle of the cycle. The different proposed states in our model are shown in the figure below.
The different considered states are:

1. Non-user
2. Has sampled
3. User
4. Ex-user
5. Dependent-not methadone-treated
6. Dependent methadone-treated+other drugs
7. Dependent methadone-treated
8. Abstinent
9. Death

The triangles in the figure illustrate the possible "jumps" from one state to another during a given cycle. The transition probabilities, i.e. the probabilities of moving from one state to another in the given time period, are to be obtained from different literature data. For instance, the probability of moving from "non-user" to "has sampled" is to be based on reported incidence rates; the probability of moving from "dependent methadone-treated (+other drugs)" to "Abstinent" is based on success rates of in helping people to stay off heroin.


Population
Non-user
1.0000
No change
0.9947
Non-user
Sample
0.0006
Has Sampled
Death
0.0047
Death
Has Sampled
0
No change
0.9063
Has Sampled
User
0.0890
User
Death
0.0047
Death
User
0
Stop using
0.0270
Ex-user
Still using
0.8062
User
Become dependent
0.1570
Dependent-Not treated
Death
0.0098
Death
Ex-user
0
Remain ex-user
0.8602
Ex-user
Re-use
0.1300
User
Death
0.0098
Death
Dependent-Not treated
0
Become Abstinent
0.0072
Abstinent
Stay dependent
0.8698
Dependent-Not treated
Enter treatment
0.0860
Dependent-Treated Metha+other drugs
Death
0.0370
Death
Dependent-Treated Metha+other drugs
0
Abort treatment
0.3880
Dependent-Not treated
Continue treatment
0.3221
Polydependent
0.6860
Dependent-Treated Metha+other drugs
Become monodependent
0.3140
Dependent-Treated Metha
Detoxified
0.2800
Abstinent
Death
0.0098
Death
Dependent-Treated Metha
0
Abort Treatment
0.3880
Dependent-Not treated
Continue treatment
0.1821
Dependent-Treated Metha
Detoxified
0.4200
Abstinent
Death
0.0098
Death
Abstinent
0
Remain abstinent
0.3601
Abstinent
Lapse occasionally
0.1300
User
Dependent-Not treated
0.5000
Dependent-Not treated
Death
0.0098
Death
Death
0

Justification of states and cycle length

The model states and their definitions are derived from diagnoses and course specifiers commonly found in the medical literature, which was our main source of information to create the model. In order to include sources of information from other fields (Epidemiology, Health Economics, Behavioural Economics…) it was deliberately decided that the diagnosis inclusion criteria had to be taken broadly. The intention was to extend the sources of information and add state transitions not found in the medical literature. For instance, the state transition "Sampler" is not a medical diagnosis. It is found in Behavioural Economics and Epidemiological studies.

In this model, the "stages" or "cycles" are periods of 6 month. Diagnosis criteria of substance use disorders as found in the medical literature require sustained changes. Course specifiers can be applied only after the criteria have been present for at least one month. Although it has been reported that transitions could sometimes occur in shorter periods of time, since our model was created mainly with medical data, 6 month cycles are justified .

Table 5: Definitions of the states used in the Markov model.

Non User	Refers to those who have never used heroin
Sampler	Refers to those who "sample" heroin for the first time. More specifically it indicates the very first opiate use.
User	Refers to those who use heroin repeatedly without clinically and sustained distress. The pattern of substance use is not better accounted for by dependence.
Ex User	Can be applied after the criteria for remission from heroin use have been present for at least 1 month
Dependent-not methadone treated	Refers to a maladaptative pattern of heroin use leading to tolerance, withdrawal syndromes, substance taken in larger amounts and over larger periods of time than intended. Important social, occupational or recreational impairment. Methadone is not used
Dependent-not methadone treated + other drugs	This specifier is used if the individual is on a prescribed methadone medication, but criteria for dependence or use of heroin are also present.
Dependent-methadone treated	This specifier is used if the individual is on a prescribed methadone medication. Criteria for dependence or abuse have not been met for at least one month except tolerance to, or withdrawal from methadone.
Abstinent	Can be applied after the criteria for remission from opiate dependence have been present for at least 1 month
Death	Applies for death related or unrelated to drugs.

5.2. Logic of the model calculation: the demand function

The key variable to be calculated by the model is the ***demand for heroin***. This demand will be expressed in grams of heroin for the individuals in our cohort. We are not referring to 1g of heroin 100%, but to 1g of heroin as it is perceived and priced by dealers and users. According to economic theory, the demand depends mainly on three general parameters: the available income of the consumer, the income of the consumer, and the price of the consumed goods.

The demand for heroin within a given time interval of 6 months (e.g. period 0) can be calculated by dividing the income spent on heroin by the price per gram of heroin (Ph). The income spent on heroin is calculated by multiplying the total available income of the consumer with the proportion of that income spent on heroin (proportion H):

$DEMAND_0 = Y_0 * proportionH / Ph_0$

As time evolves, the market situation may change, affecting the heroin price or the income of the consumer. The relative extent according to which the consumer adapts his demand for heroin in a subsequent period of 6 months to a price change is expressed by a term called "elasticity of the demand for heroin towards price changes" (E^p_{hh}).
In general economic theory, a price-elasticity (E^p) is expressed by dividing the proportional change in demanded quantity (Q) by the proportional price (P) change. Mathematically:

$$E^p = (\Delta Q/Q) / (\Delta P/P)$$

In a normal market, the outcome of E^p is a negative number, representing the negative relationship between price and demanded quantity: as prices go up, the demanded quantity will decrease. An absolute value of >1 of E^p indicates that the demand is elastic. A demand is elastic when a certain proportional change in a parameter leads towards a proportionally larger change in the demand for a certain good. For instance, a price decrease of 10% causes an increase of 12% in the demand (E^p=1.2). A demand is inelastic when a certain proportional change in a parameter leads towards a proportionally smaller change in the demand for a certain good. The absolute value of E^p_{hh} is hereby <1. An elasticity of zero means that the consumer is insensitive towards the price changes: the demand remains the same.
Knowing the above, the demand for heroin in period 1 can be expressed as a function of the demand of the previous period:

$$DEMAND_1 = DEMAND_0 + (E^p_{hh} [(Ph_1 - Ph_0)/Ph_0] * DEMAND_0)$$

Whereby:
$DEMAND_0$ = demanded quantity (in g) of heroin in period 0
E^p_{hh} = The price-elasticity of the demand for heroin
Ph_0 = The price in period 0 of heroin

Not only prices may change, also the income of the consumer may vary. The sensitivity of the demand towards changes in the income is expressed by the "income-elasticity of the demand for heroin" (E^y_h). The logic for income elasticity is the same as for price elasticity, with that difference that there is a positive relation between income and demanded quantity. Including this income sensitivity in our model results in the following formula of the demand for heroin:

$$DEMAND_1 = DEMAND_0 + (E^p_{hh}\,[(Ph_1-Ph_0)/Ph_0] + E^y_h\,[(Y_1-Y_0)/Y_0]) * DEMAND_0$$

In which:
$DEMAND_0$ = demanded quantity (in g) of heroin in period 0
E^p_{hh} = The price-elasticity of the demand for heroin
E^y_h = The income-elasticity of the demand for heroin
Ph_0 = The price in period 0 of heroin
Y_0 = The available income in period 0

The above formula implicitly assumes that heroin is the only available drug on the market. This is obviously not the case.
The experiments of Petry and Bickel (1998) showed that depending on the price of heroin but also on the price of other addictive goods, heroin users may shift their consumption towards other drugs like Valium® and cocaine. Other opiates, cannabis and alcohol may also be substitutes for heroin, but to our knowledge, there is no data illustrating the cross-elasticity of demand towards their prices. A heroin consumer may thus "substitute" his heroin consumption temporarily by cocaine or Valium® for instance. The extent to which this will be the case is expressed by the "cross-elasticity of the demand for heroin towards the price of e.g. Valium® and cocaine" (E^p_{hv} and E^p_{hc}). Consequently, our demand formula has to be adapted to:

$$\mathbf{DEMAND_1 = DEMAND_0 + (E^p_{hh}\,[(Ph_1-Ph_0)/Ph_0] + E^y_h\,[(Y_1-Y_0)/Y_0] + E^p_{hv}\,[(Pv_1-Pv_0)/Pv_0] + E^p_{hc}\,[(Pc_1-Pc_0)/Pc_0]) * DEMAND_0}$$

Whereby:
$DEMAND_0$ = demanded quantity (in g) of heroin in period 0
E^p_{hh} = The price-elasticity of the demand for heroin
E^y_h = The income-elasticity of the demand for heroin
E^p_{hv} = The price-elasticity of the demand for heroin towards prices of valium
E^p_{hc} = The price-elasticity of the demand for heroin towards pices of cocaine
Ph_0 = The price in period 0 of heroin
Pv_0= The price in period 0 of valium
Pc_0= The price in period 0 of cocaine
Y_0 = The available income in period 0

5.3. Specific data to populate the model

The current chapter reports on the data from the literature, that were found to be relevant for populating the model. Finding appropriate data to populate the Markov model was difficult. Not only there are many data gaps, most data found were prevalence based data rather than incidence based data. However, some probabilities, not readily available from literature could be derived indirectly from other existing data.

The model presented in the basecase is a general model. When analysing different subpopulations, the applied probabilities may differ. For instance, the current proportion drug use in prisoners would lie between 30 and 90% according to the EMCDDA (2000), 20 to 50% of the prisoners would be problematic drug users. Between 15 to 50% of the total jail population would be drug offenders; 75% of these would concern dealing/trafficking. These figures are obviously very different from the average figures in the general population, where cannabis use was the most frequent, varying between 1 to 9% in EU countries for the last 12 months. Use of other illegal substances would rarely exceed 1% among adults and is under 3% among young adults (EMCDDA, 2000).

Further on in this report, the subpopulations, for which the model can run separately, will be described.

This chapter is organised in such a way that for each health state of the model, an overview is presented of the data that were found in literature and how these data were applied into the model.

5.4. The health states

5.4.1. General population

Among the general population, 1% have ever tried heroin or other illicit opiates in the EU. This percentage is higher (1%-2%) when considering a subpopulation of school attendees or youth population. (EMCDDA, 1999 and 2000).

Similarly, Van Etten et al. (1999) found that in the US, an estimated average 5% of 131226 residents >12 years have had an opportunity to try heroin (7.8% for males and 3.2% for females), and 1% had used it (one or more times). The median age of the first opportunity for heroin was 18 for males and 17 for females, although the male-female difference was statistically not significant. Hence, in some age groups, the probability of sampling heroin is clearly higher than for other age groups. A person entering our model will consequently have a higher probability of sampling at some points in time compared with other points in time. However, since we work with an average-aged population, a constant sampling rate can be applied. Knowing that the median age in the US is approximately 35 years (OECD Health data 1998), the incidence per 6 months can be calculated with a risk-to-rate formula ($Rate_{6mo} = 1- (1-Risk_{n\ mo})^{6/n}$), translating a 23-year (=35-12) risk (1%)

into a 6 months incidence. The result of this calculation is a 6-month incidence rate of 0.0003. This means that every 6 months, 0.03% of the general population would try heroin.

On the other hand, the annual report of the EMCDDA in 1999 states that in the European Union, an estimated number of 4.0 per 1000 population is a problematic opiate user (about 1.5 million people), of whom about 1 million (2.7 per 1000 population) probably meet the criteria for dependence. By means of control, the model was calculated back in order to see what % of sampling would be "required" under the current model assumptions in order to approximate 4 per 1000 problematic opioid users and 2.7 dependent users after 20 years. This 6-month sampling rate was 0.00085, generating a 2% of the population who would have sampled over the 20 years of our analysis. Indeed, surveys on sampling may well underestimate the true sampling rates. **In our basecase, we will apply the average rate of 0.0003 and 0.00085: 0.0006**. This results in a total of 1.6% of the general population who has sampled after 20 years of analysis.

The 6-month **mortality** in the general population is set at **0.47%** (OECD statistics, 1997).

The sum of the probabilities of each subtree has to add up to 1, which makes that the proportion of people **remaining non-users** (not sampling and not dying) comes down to **0.9947** (1-0.0047-0.0006) per 6 months.

5.4.2. Has Sampled

No information could be found on the proportion of people who tried heroin, and sticked to that first-time use (samplers). 17% of people who had an opportunity to use heroin made their transition to their first use within one year (Van Etten and Anthony, 1999). Considering this the proportion of people being more "susceptible" for heroin use than those who did not use within one year after the opportunity occurred, we assume an equal proportion making the transition from sampling to more frequent heroin use (within one year). Applying the risk-to-rate formula results in a 6-month probability of **8.9%** to make the transition from **sampling to more frequent use**.

The one-time procured quantity of heroin at sampling is set at **1g** (source: expert opinion). This is the demand that was entered into the model at the health state "Has sampled".

The **probability of dying** at the health state "Has sampled" is considered no different from that of the general population (**0.47%**).

Knowing that the sum of probabilities of each subtree has to add up to 1, the proportion of people **sampling heroin but not using further** comes down to **90.63%** (100%-8.9%-0.47%).

Note that samplers are not expected to show elasticity towards neither prices nor income, since it involves only the first time use of heroin.

5.4.3. User

In the European Union, an estimated number of 4.0 per 1000 population is a problematic opiate (mainly heroin) user (about 1.5 million people), of whom about 1 million (2.7 per 1000 population) probably meet the criteria for dependence. This means that an estimated 67.5% of problematic drug users would be dependent. Approximately 20% of all problem users in the EU receive substitution treatment (EMCDDA, 1999 and 2000). This percentage will however vary a lot according to countries as access to substitution treatment differs a lot.

A report of the NHSDA (National Household Survey on Drug Abuse, 1996), analysing the need for treatment stated that 47.6% of people who used heroin during the last year were dependent. This large survey is performed in the US population > 12 years since 1979.

When considering a group of 100 users of heroin, the above implicates that 100-47.6 = 52.4 out of these 100 used heroin during the past year, but were not dependent, representing in our model the sum of transitions from user to user, from user to ex-user, and from user to death.

The above 47.6% of dependent heroin users during the past year is a mixed group, consisting of people being dependent already for more than one year and a group of users who have become "newly" dependent during that year.

In the same report of the NHSDA (1996), the authors state that within the population of dependent users (DSM-III criteria), on average 45% of persons also met the DSM-III criteria for heavy drug use and on average 35% of the persons meeting the DSM-III criteria for heavy drug use also met the DSM-III criteria for dependence. This overlap means that there is a proportion of people being in the "zone" between non-dependent user and dependent user. We assume therefore that on average 45% of the 47.6% dependent users (=21.4%) may be considered as new dependents, and 26.2% (=47.6%-21.4%) are already dependent for more than a year.

In sum, out of the 100 people having used heroin during the past year, 52.4 (non-dependent users)+21.4 (newly dependent users) = 73.8 started as non-dependent heroin users, and 47.6-21.4 = 26.2 were already dependent. The probability of making the transition **from the state "User" to "Dependent-Not Treated"** in our model comes consequently down to 21.4/73.8 = 29.0% per year. Recalculating this figure to a 6-month rate by the risk-to-rate formula results in a **transition probability of 15.7%**.

The UK national report of the EMCDDA (1999) states that, although the number of people who ever tried heroin is increasing, the number using regularly or occasionally is not; i.e. two-thirds of those who have used are essentially non-users now. This is a rough figure, however, no further information on the transition **from user to ex-user** could be found. Our model runs for 20 years (40 periods of six months). Suppose that after 20 years, the cumulative proportion of users who

became ex-users is indeed two thirds (66.7%). Recalculating this figure to a 6-month rate generates a **transition probability of 2.7%**.

An injecting drug user would have a 20-30 times higher risk of death by overdose, HIV infection, accident and suicide than non-drug users of the same age. Note also that injecting drug users have a higher risk of death than non-injectors. (EMCDDA, 1999). Injecting drug use is more common among opiate users and ranges in the EU from 14% (The Netherlands) to over 80% (Greece and Luxembourg) (EMCDDA, 1999). In Belgium, approximately 33.3% of heroin users were injecting drug users.

However, no data were found on the overall death rate of non-dependent heroin users. It is assumed that the death rate among this population is lower than for dependent users, yet higher than for the general population. Therefore, the assumption is made that these people have the same **mortality rate** as people in a methadone treatment program (**0.98%**). The logic and calculation of this rate is discussed in more detail in section 5.4.6.. Note that this may well be an overestimation of the true mortality rate.

The transition probability **user-user** in our model is then calculated by 1 minus the sum of the other probabilities of this subtree and comes down to **80.62%**.

No separate data were found in literature on the price-and income elasticities of non-dependent heroin users separately, like Petry and Bickel (1998) did for dependent heroin users. However, as described in section 3.4.2., Bretteville-Jensen (1999) showed empirically that there is a difference in short-sightedness (as expressed by the discount rate) between active misusers, non-misusers, and ex-misusers of drugs. Misusers were described as people having injected heroin during the last month. The economic theory as described earlier in this report, additionally showed that, the higher the discount rate, the more short-sighted a person is, and the less economically rational this individual will behave.

Following this logic and considering the discount rate of the active users as an index, set at 100%, it could be derived that less heavy heroin users were on average 91% less short-sighted, as indicated by their lower discount rate. Applying this to the price-elasticity of heroin demand towards its own price, generates a **price-elasticity of –3.07, i.e. 91% more elastic than –1.61, which was the elasticity for heroin addicts in Bretteville-Jensen (1999).** The same logic and calculation was followed for calculation of the **income elasticity** giving a result of **1.15**.

5.4.4. Ex-user

No data were found in literature on transitions from ex-user to user. However, probabilities have been estimated by derivation from other figures.

The 6-month transition probability **from ex-user to user** is set at **13%**. This figure is based on a study of Broers et al. (2000), who reported that 6 months after a detoxification program, 13% of people had lapsed occasionally. We are well aware that people in a detoxification program may differ from the "user" population in our model. However, no other data were found on people re-using heroin without being dependent.

No data were found on the **mortality** at the population of people who are ex-users (non-dependent) of heroin. We assumed that the probability of dying is lower than a heroin user, but also higher than people who never used heroin. Therefore, the assumption is made that these people have the same mortality rate as people in a methadone treatment program (**0.98%**). The logic and calculation of this rate is discussed in more detail at section 5.4.6. However, this may well be an overestimation of the mortality rate.

The probability of **remaining an ex-user** can then be calculated as 100% minus the sum of the above two rates, coming down to **86.02%**.

One could argue that an ex-user remains "sensitive" in a way towards income and prices of heroin and other drugs. However, this has not been programmed separately into the model. It is believed that the strength of "attraction" of heroin towards the ex-users is reflected in the probability of ex-users restarting heroin use (transition probability of ex-user to user).

5.4.5. Dependent-Not treated

Based on expert opinion, the median latency time between the moment of becoming dependent and the first treatment demand was set at 4 years. This means that 50% of people becoming newly dependent are dependent for 4 years before entering treatment for the first time. Applying the risk-to-rate formula in order to calculate the 6-month rate of newly dependents entering treatment gives a result of 8.3%. A study of Widman et al. (1997) in 409 subjects in a methadone maintenance program reported a first treatment demand at the age of 25.9 years. The average age of the study population was 36.9 years. In this period of 11 years, an average of 3 treatment entries were reported, i.e. every 3.7 years. Arbitrarily considering the mean equal to the median (due to lack of better data), and applying again the risk-to-rate formula, a 6-month rate of treatment entry in these people of 8.9% is calculated.

Data from the NHSDA (1996) showed that on average 45% of dependent users are "newly" dependents. This means that 100%-45%=55% are already dependent users. These figures are used

to calculate a weighted average 6-month rate of **entering treatment** when being in the state "Dependent-Not treated" of **8.6%**.

The Office of National Drug Control Policy (1989) made the assumption that approximately 25% of heavy drug users would stop using drugs without formal treatment and another 25% were hard core addicts that were too difficult to reach for treatment programs (NHSDA, 1996). Since no other data are found, we will adopt the assumption that one quarter of heavy drug users stopped using without treatment by the end of our 20-year analytical period. This means that the 6-month rate of **stopping heavy use without treatment** would be **0.72%.**

Historical data, presented by Gearing et al (1974) showed that individuals who did not have access to methadone had 6.8 times the mortality rates of entrants in a methadone treatment program (Barlett (1999)). Gronbladh et al. (1990) reported in a Swedish study an annual **death rate** of 7.2% among untreated heroin users. Recalculating the Swedish figure by the risk-to-rate formula for a period of 6 months generates a **transition probability of 3.7%.**

The probability of remaining dependent and not treated is calculated by 1 minus the sum of the other probabilities of the subtree and comes down to **86.98%**.

The price and income elasticities applied at this health state are the ones as described by Bretteville-Jensen (1999) and Petry and Bickel (1998) (see earlier): -1.61 for the own price-elasticity of heroin, 0.82 for the cross-price elasticity of heroin towards the price of cocaine, and 0.6 as the income elasticity.

5.4.6. Dependent-Methadone-treated + other drugs

Broers et al. (2000) found that after 1 month, 35% of the participants of a detoxification program were completely abstinent *(*21% when excluding those in residential treatment). After 6 months, 37% were **abstinent** (**28%** when excluding those in residential treatment).

Wilson et al. (1994) reported an 83% retention rate at 26 weeks in their MMT program. However, the figures of Sees (2000) are preferred for our model since the latter concerned a more relevant population according to the research criteria of our study. Sees reported a treatment retention rate of 82.4% at 11 months. Applying the risk-to-rate formula on this 82.4% over 11 months, results in a **6-month retention rate of 61.2%.** This means that within 6 months, **38.8%** (=100%-61.2%) of people starting a MMT **abort the program**. Of the people in treatment, **68.6% continued to use heroin** (Sees et al., 2000).

An Australian study, reporting on a project where high-dose methadone was administered, and clients could stay indefinitely into the program showed a 1.1% yearly death rate (Caplehorn, 1994). This is in line with the 1% annual mortality rate reported by Zanis and Woody (1998) for people completing the MMT program. Moreover, **drop-outs** from a methadone program showed a

3.5 times higher death rate than completers. The probability of dying applied into the model is a weighted average death rate for completers and aborters of the treatment program, resulting in a probability of **0.98%** of dying.

Summarizing the above gives that of those people starting treatment, 38.8% abort it. This means consequently that 100%-38.8%= 61.2% continue the program. These 61.2% may die (0.98%), leaving 60.22% (61.2%-0.98%) of people who become detoxified (28%) or continue the treatment (32.2%=61.2%-0.98%-28%). Of the people in treatment, 68.6% continued to take heroin over 6 months, which means that 68.6% are considered polydependent in our model, and 31.4% (100%-68.6%) become monodependent at 6 months.

The same elasticity values were supposed for polydependent people in treatment as for people being dependent without treatment.

5.4.7. Dependent-Methadone-Treated

The same transition probabilities are applied at this health state as in the state Dependent-Methadone-Treated + other drugs for treatment cessation (38.8%) and death (0.98%). These people are no longer polydependent. Therefore, the distinction between "Dependent-Methadone-Treated" and Dependent-Methadone-Treated+other drugs" is made because the demand for heroin is zero at the state "Dependent-Methadone-Treated", while this is not the case for people still using heroin while in substitution treatment.

The fact that only methadone is used by these patients and no longer heroin, makes suspect that these people may have a better chance of becoming abstinent. However, one might argue that these people are still dependent to opiates, so that the probability of becoming completely abstinent is not that different from polydependent people. In our basecase model, we will assume a double as high probability of becoming abstinent for monodependent people after one year, and 50% higher after 6 months (source: expert opinion). Multiplying thus the 28% abstinence rate of 5.4.6. with a factor 1.5 gives an **abstinence rate of 42%** per 6 months. The probability of "**continue treatment**" (**18.21%**) is then calculated by 1-sum of the other probabilities of this subtree.

5.4.8. Abstinent

Broers et al. (2000) found that 1 month after detoxification, 65% of the patients were re-using drugs, of which half were dependent again, and half had used occasionally. After 6 months**, 13% had lapsed occasionally** and **50% were physically dependent again**.

No data were found on the **mortality** at the population of people who are abstinent after heroin dependence. We assumed that the probability of dying is lower than a dependent heroin user, but also higher than non-users. Therefore, the assumption is made that people, abstinent after heroin dependence have the same mortality rate as people in a methadone treatment program (**0.98%**).

The remainder of people (**36.02%**) **stay in the state "abstinent"**, and this is calculated by 1-sum of the other probabilities in this subtree.

As for ex-users, one could argue that people, abstinent after dependent use remain "sensitive" in a way towards income and prices of heroin and other drugs. However, this has not been programmed separately into the model. It is believed that the strength of "attraction" of heroin towards the ex-dependent people is reflected in the probability of abstinent people restarting heroin abuse (transition probability from abstinent to dependent).

5.5. Objective determinants of heroin demand

After review of the existing literature on economic behaviour of drug users and addicts, we decided to adopt the basic framework of the theory of rational addiction as developed by Becker and Murphy (1988). Within this framework, the price of addictive goods is an essential determinant of the demand for addictive goods. The extent to which a heroin user changes his demand in function of price changes of heroin, its substitutes and its complements, is in its turn determined by the price elasticity of the demand towards these price changes (see earlier in this report).

National Reports of the BIRN (Belgian Information Reitox Network) on drugs (1999) reported the wholesale and retail prices from 1993 to 1998 as reported in the table on next page. Apparently, prices were decreasing in the early nineties, but were stabilizing during 1997-1998.

The price of heroin was set at 35 Euro in the model, as presented in the table. As time evolves, prices will not remain static. Instead, as a consequence of the market play of offer and demand, prices go up and down. In our model, we assume a constant price with one price increase of x% in the middle of the 20-year analytical time horizon, due to an intervention causing the price to go up.

Table 6: Evolution of the price of heroin

Product	Wholesale (BEF/g) (from supplier to dealer)				Retail sale (BEF/g) (from dealer to consumer)			
	1993	1995	1997	1998	1993	1995	1997	1998
Heroin (brown)	950	600-900	600-1000	600	3000-4000	800-2250	1500	1500
Heroin (white)			500-1000				800-1000	
Cocaine	950-1650	460-900	800-1200	700	1500-3000	1200-1750	1200-2000	2000
	Wholesale (Euro/g) (from supplier to dealer)				**Retail sale (Euro/g) (from dealer to consumer)**			
	1993	1995	1997	1998	1993	1995	1997	1998
Heroin (brown)	24	15-22.5	15-25	15	74-92	20-56	35	35
Heroin (white)			12-25				20-25	
Cocaine	24-41	12-22.5	20-30	17.5	35-74	30-68	30-50	50

Another variable determining the heroin demand is income. No data on the income nor on the proportion of the income spent on heroin consumption per health state were found. The study of Sees et al. (2000) among heroin addicts attending methadone detoxification and maintenance programs reports an average consumption of 7.01g per week at baseline. Applying the above price of 35 Euro per gram of heroin, results in an average spending of 260 Euro per week, or 6255 Euro per 6 months for a person in the state "Dependent-Not Treated". Based on expert opinion, we suppose that a consumer in the state "Dependent-Not Treated" spends 80% of his income on heroin. Recalculation towards 100% generates a 6-month income (Y0 in the model) of approximately 7820 Euro. Note that the total income is considered here, originating from legal and illegal activities.

The value of the proportion of the income, spent on heroin is set at **30%** for a dependent heroin user under methadone treatment (source: expert opinion). A non-dependent user consumes about 1g of heroin per week (source: expert opinion). This is approximately 14.3% of the consumption of an untreated dependent user. Consequently, a non-dependent user is expected to spend **11.4%** (0.143*80%) of his total income on heroin.

In order to be able to simulate the wage evolution over time, the website of the Belgian Federal Information Service was consulted. The gross hour wages of industrial workers were increased by 2% between 1995 and 1996. Therefore, a yearly increase of the total income by 2% will be taken into account in the model.

6. Results on the cohort level

This chapter presents the results of calculating the model for a cohort of 1000 people, programmed with the data described above. First, the basecase results for the general population will be presented, after which the impact of different possible intervention scenarios is analysed. In a third section, the results of the analyses for different subgroups will be presented. Separate analyses have been performed for both genders and for people with and without ASPD.

6.1. Basecase results

Running the model for the cohort under the current assumptions generates an average basecase demand of 20450g over 20 years, or 20.45g per person in the general population. The demand per person when being in a certain state is presented in table7.

Table 7: Demand per state per person

Health state	**20-year probability**	**6-month demand per person**
General population	80.8%	0g
Has sampled	0.54%	1g
User	0.30%	26g
Ex-user	0.05%	0g
Dependent-Not treated	0.62%	179g
Dependent-Tx Metha+other	0.07%	67g
Dependent-Tx Metha	0.01%	0g
Abstinent	0.04%	0g
Death	17.5%	0g

The results show that over a period of 20 years, 80.8% of the general population will never try heroin. The cumulative mortality after 20 years is 17.5%. Figure 2 shows the 20-year evolution of the cumulative probabilities for people who used heroin more than once. This means that by the end of year 20 (cycle 40), 0.62% of people entering the model at point 0 will be untreated dependent heroin users.

Figure 2: Cumulative probability evolution over 20 years for people having used heroin more than once.

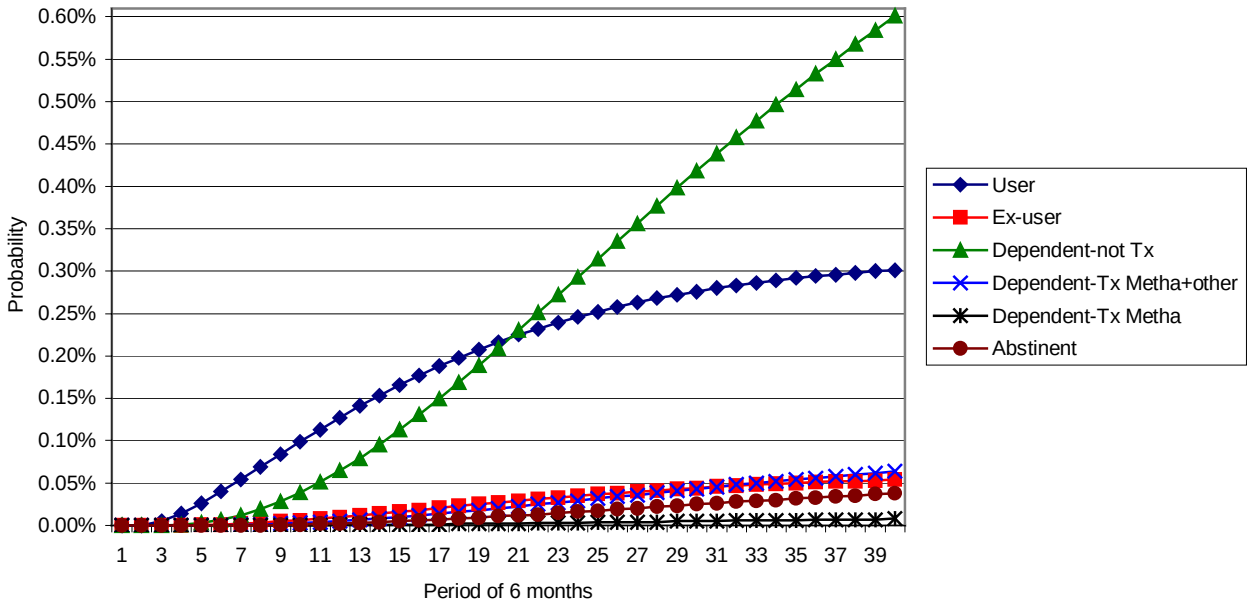


Figure 2 shows that the number of users grows during the first 9 years of our model. After that, the graph shows that this curve is caught up by the curve representing the number of people being dependent and untreated. This evolution from user to dependent user shows clearly the addictive character of heroin. The other curves show also an increasing trend over 20 years, showing the increasing proportion of people stopping or treating their addiction.

6.2. Impact of changes

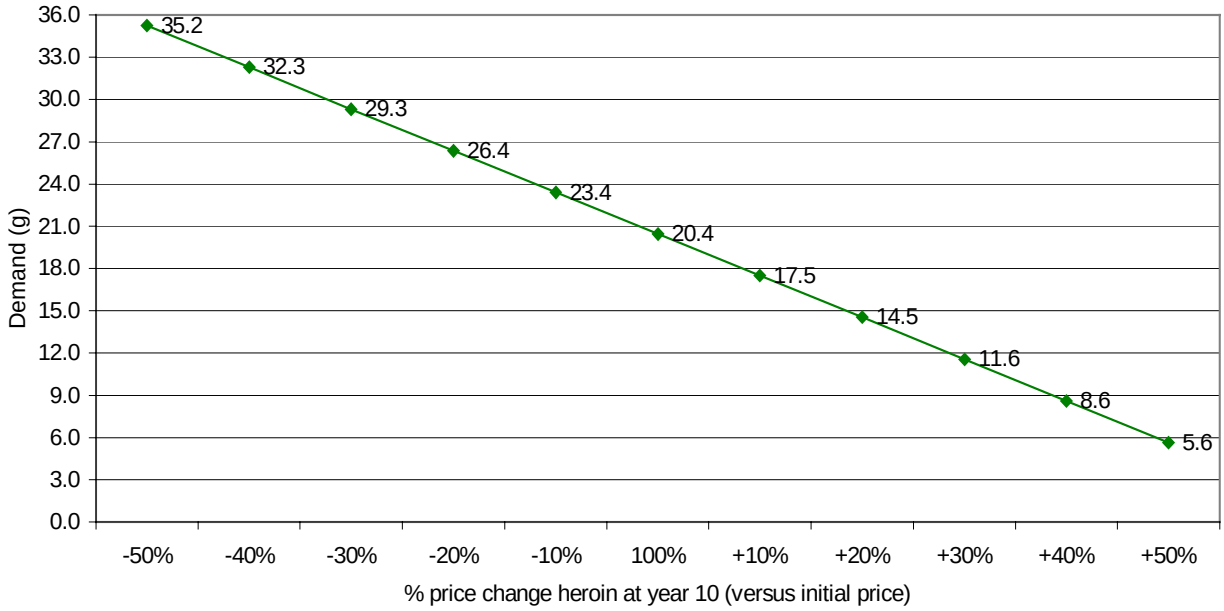
Our model is intended to serve as a dynamic tool that can be used for analysis of different changes in the hypotheses and interventions in the heroin market. Therefore, several scenarios were analysed and the results are presented in this section.

6.2.1. Price changes

The impact of different measures was tested. Interventions on the supply side on the market, like a more intensive repressive policy, whereby the number of arrests would increase for instance, may drive up the unit price for heroin. Not only will the quantity offered on the market decrease, but also an increased risk for police capture is expected to drive the price up. Oppositely, a more tolerant policy may have a tempering effect on the price. The market play itself may also cause price changes. If the number of heroin users increases, for instance, the total demand for heroin will increase, causing a price increase when the supply side cannot ‘keep up’ with this increased demand (the heroin becomes more ‘scarce’). In its turn, this price increase will then temper the demand.

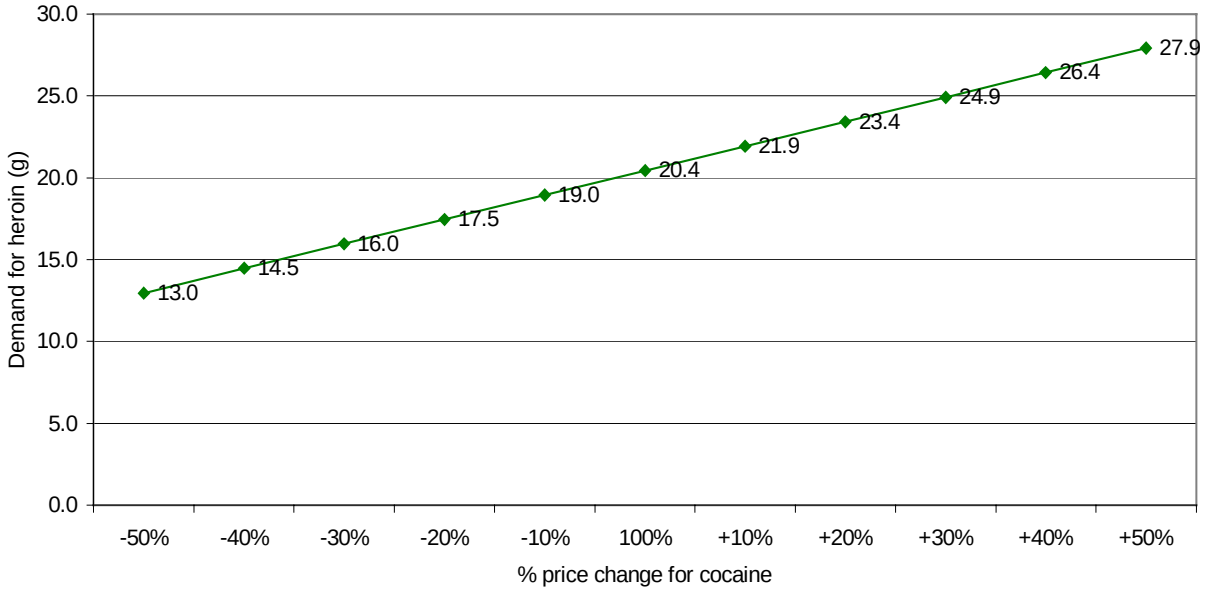
Suppose that the **price increases** due to external effects (repressive measures) with **50% at year 10**. Due to a combined game of income and price elasticities at the different health states, we can see that in the end, the additional price increase causes long term demand decrease in our cohort of **72%, to 5.6 g per person** compared with the basecase. This is a pure decrease, i.e. on condition that supply side does not respond. Oppositely, suppose an intervention affecting the heroin price at year 10 causes a **price decrease of 10%** compared with our initial heroin price; the demand goes up with **15%, up to 23.4g per person**. This is illustrated in figure 3.

Figure 3: Impact of different heroin price interventions at year 10.



Not only can the price of heroin itself change, variations in prices of other substances may well have an influence on the demand for heroin. As seen in this report, the demand for heroin may additionally be determined by price changes for cocaine, since there was found to be a substitution effect between heroin and cocaine. In our basecase model, the price of cocaine was held constant over 20 years, figure 4 shows the effect of variations in this price on the results. A price increase (decrease) of 20% for cocaine causes a 15% higher (lower) demand for heroin.

Figure 4: Impact of price changes for cocaine on the individual heroin demand.

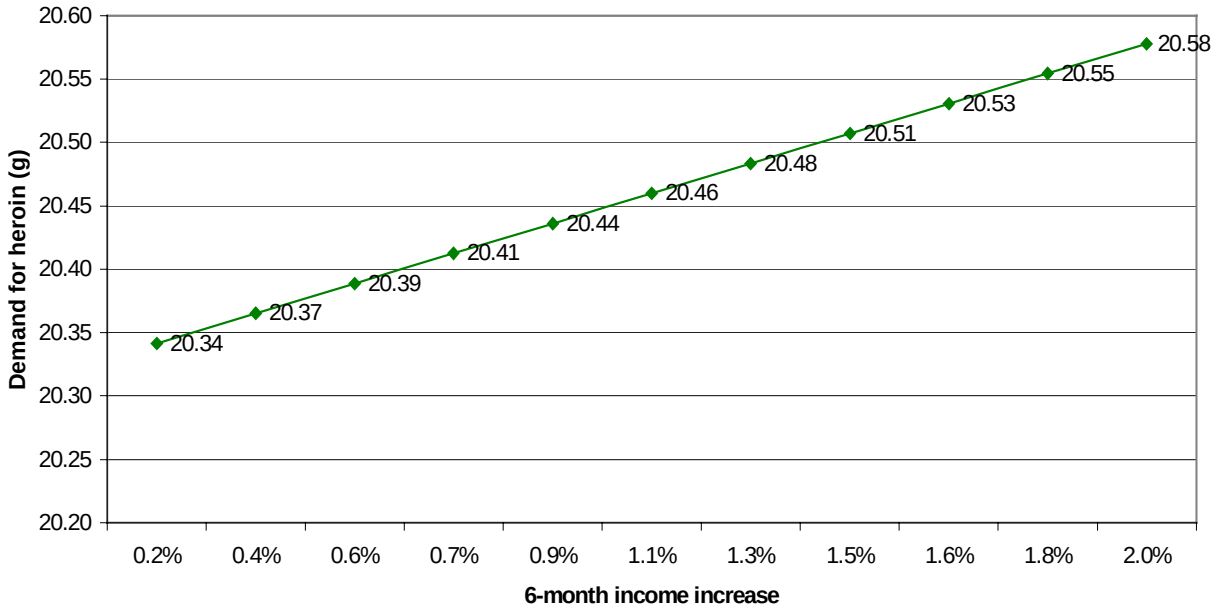


6.2.2. Income changes

In our basecase model, a steady upward evolution of the available income (legal +illegal) by 1% per 6 months was programmed. Sees et al. (2000) reported that among heroin dependents, 64% of income was illegal, and 36% legal. This is also confirmed by expert opinion. Suppose that, through a set of measures, the illegal income can be reduced by 50%. This has an impact of 0.84% per 6 months on the total income. Oppositely, when a heroin addict can increase his income from criminal activities by 50%, this will have an upward impact of 0.84% per 6 months on the total income. The results of these and other scenarios in between are presented in figure 5. The percentages on the X-axis indicate the 6-monthly income increase. The value corresponding with 1.5%, for instance, on the X-axis, means that the model is calculated taking a 6-month constant increase of 1.5% of the total income into account.

The graph indicates that income changes have a more modest impact on the demand for heroin in our cohort than price changes. A continuous total income increase of 2% per 6 months (2% on X-axis), for instance, instead of 1% per 6 months (basecase) causes the individual total average demand to increase by less than 1g.

Figure 5: Impact of different scenarios for income evolution.

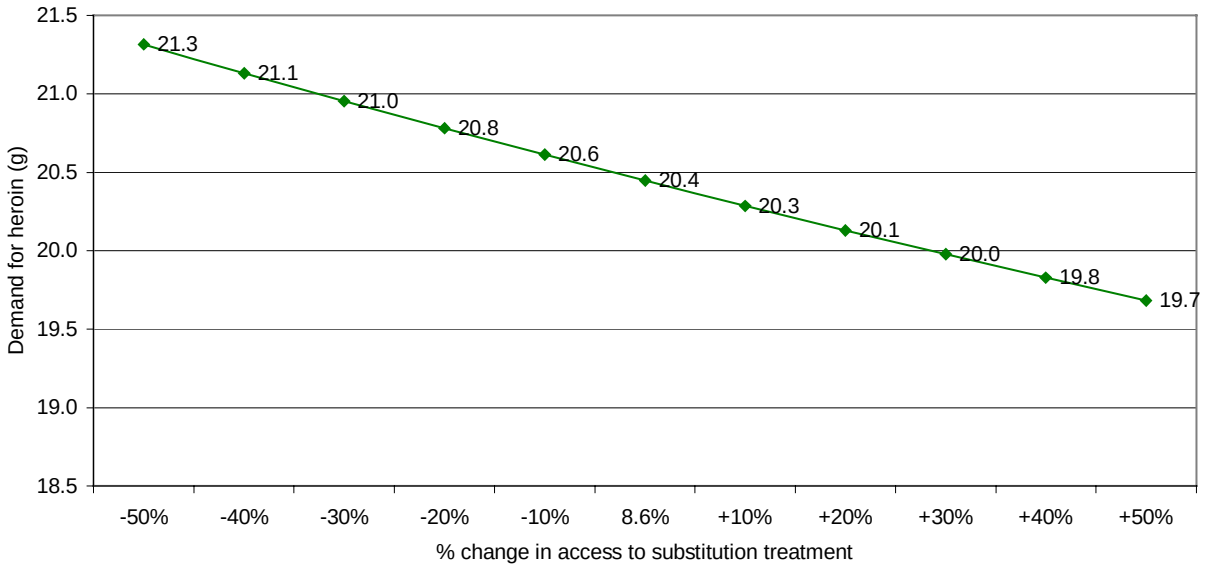


6.2.3. Changes in substitution treatment

Not only may the economic dynamics on the market itself be subject to changes, also (changes in) interventions trying to interfere in the pure economic play of demand and supply may generate an effect on the demand for addictive goods.

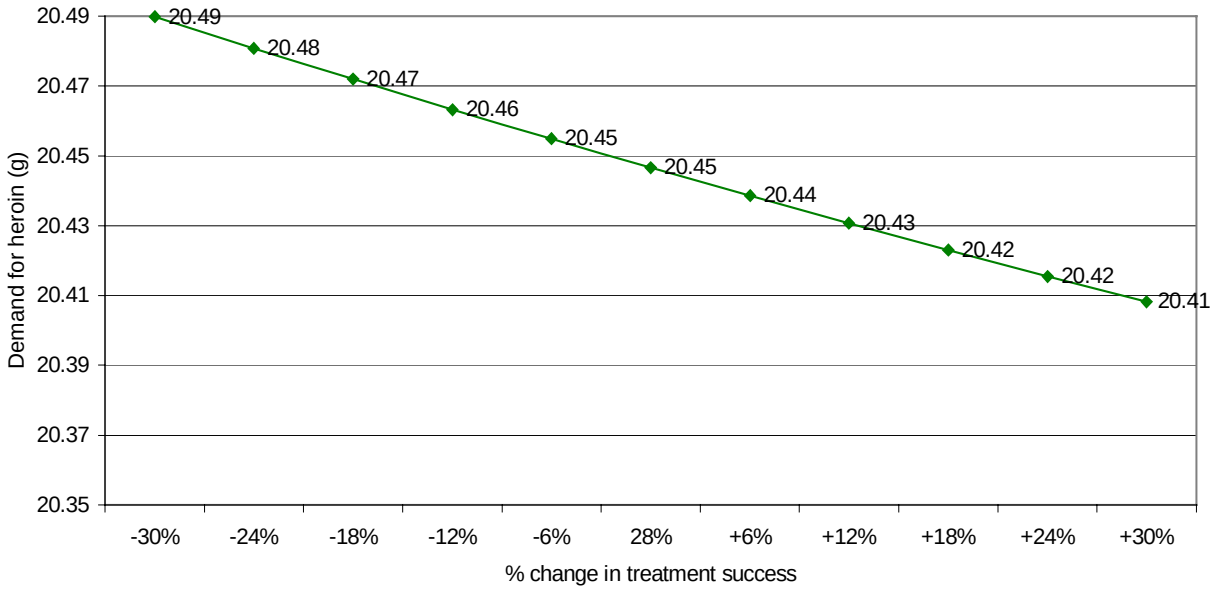
A tested scenario in this context was the impact of a better or worse access to methadone treatment. Figure 6 shows that a 50% decrease in access, reflected by the number of people entering treatment, to substitution treatment will cause a proportionally higher increase in heroin demand (4.2%) than the decrease in heroin demand (3.7%) caused by 50% better accessibility to methadone treatment.

Figure 6: Effect of changes in access to methadone treatment on the individual demand for heroin.



Within the same context, the effect of a higher 6-month success rate of substitution treatment was also tested. Figure 7 shows that a 30% increase or decrease in the success of substitution treatment has a modest impact of 0.2% on the average demand for heroin.

Figure 7: impact of changes in substitution treatment success on the demand for heroin.



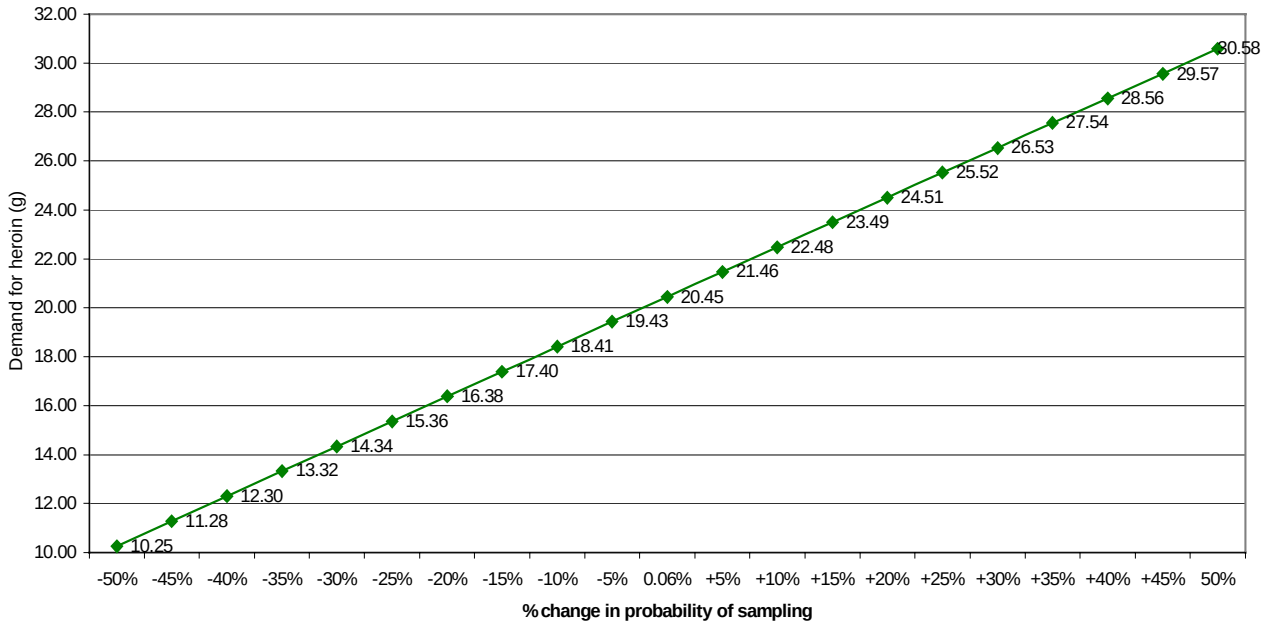
The modest impact of treatment success on the total average individual demand for heroin in our cohort may perhaps be explained partially by the high rate of abstinent people starting to reuse heroin again. In line with this, it may well be that a better treatment access has a higher impact on the demand for heroin, since that means that people spend less time in the health state "dependent-not treated", which generates the highest consumption of heroin.

In order to verify the above, the probability of re-becoming dependent after abstinence was varied. A 50% lower probability of restarting heroin use caused a decrease in the demand of 3%, while a 50% higher probability of restarting heroin use caused an increase in the demand of 1%. This could mean that measures focussing on sustaining abstinence after substitution treatment may be more desirable as measures focussing on the success of treatment itself.

6.2.4. Impact of prevention

Different projects can be elaborated with the goal of preventing people from trying heroin. In terms of our model, the effect of these type of projects is measured by their effect on the probability of sampling. Therefore, different scenarios, varying this probability for our cohort between –50% and +50% of its basecase value have been analysed (see figure 8). The figure shows clearly that variations in the proportion of people trying heroin has a large impact on the general demand for it. For instance, an increase of the sampling probability with 5% causes an increase in heroin demand of 4.9%. A decrease of the probability of sampling with 50% causes a 49.8% lower demand for heroin over 20 years in our cohort.

Figure 8: Impact of a varying probability of sampling on the individual demand for heroin over 20 years.



6.3. Analyses for subgroups

6.3.1. Differences determined by gender

Van Etten et al. (1999) found in extensive research that differences between males and females come down to the fact that males have more opportunities for trying heroin and drugs in general than females. Once an opportunity occurred, no differences could be identified anymore in the probability of actually using heroin.

The above in mind, the difference between genders in our model will consequently be determined by differences in the probability of sampling. Van Etten et al. (1999) reported a probability of using heroin (one or more times) of 1.4% for males and 0.8% for females. Recalculating these 23-year (see section 5.4.1.) risks to 6-month rates gives a 6-month probability of sampling of 0.04% for men and 0.02% for women of having an opportunity to try heroin.

However, when we compared the figures of Van Etten et al. (1999) with data from the EMCDDA (1999) in section 5.4.1., rather different outcomes were obtained, and the average between the two estimations was applied in the model. We do not have gender-specific data available from the EMCDDA on the rate of sampling, but we have seen that the average rate applied in the model was 2 times higher than the figure obtained from Van Etten et al. (1999). We will therefore apply the same rule here, and thus enter **a transition probability of sampling of 0.08% for men and 0.04% for women.**

Analysing the model for our cohort results then in a higher total average individual heroin **demand for men of 27.2g over 20 years versus 13.7g for women.** Figures 9 and 10 show clearly a higher proportion of men for instance, compared with the general population graph (figure 2), being in health states involving heroin use more than once over the 20 years. For women, we see the opposite effect.

Perhaps another path to be explored concerning this gender issue is the gender of the persons creating the opportunity for sampling for women. Since the difference between men and women would lie in the opportunity to sample, more men than women fall into more frequent heroin use, in their turn perhaps creating or offering an opportunity for sampling towards women. If this were true, measures targeting prevention in men would automatically have an additional impact on the sampling rate in women and therefore also on further heroin use. However, no evidence or argument was explored nor found at all on this topic and the above remark should be interpreted with the necessary caution.

Figure 9: Probability evolution over 20 years for MEN having used heroin more than once.

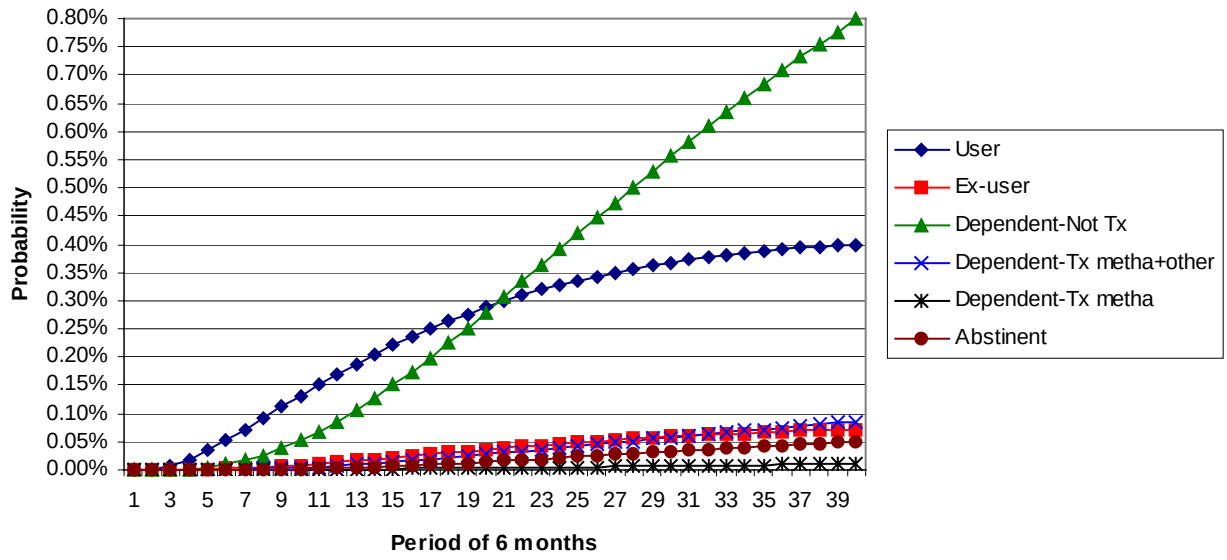
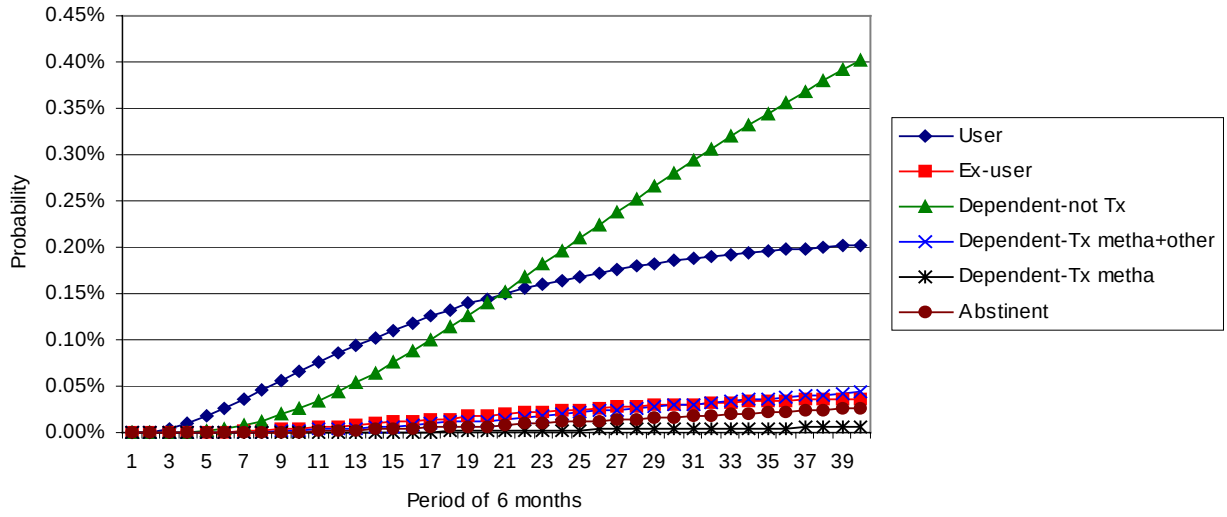


Figure 10: Probability evolution over 20 years for WOMEN having used heroin more than once.



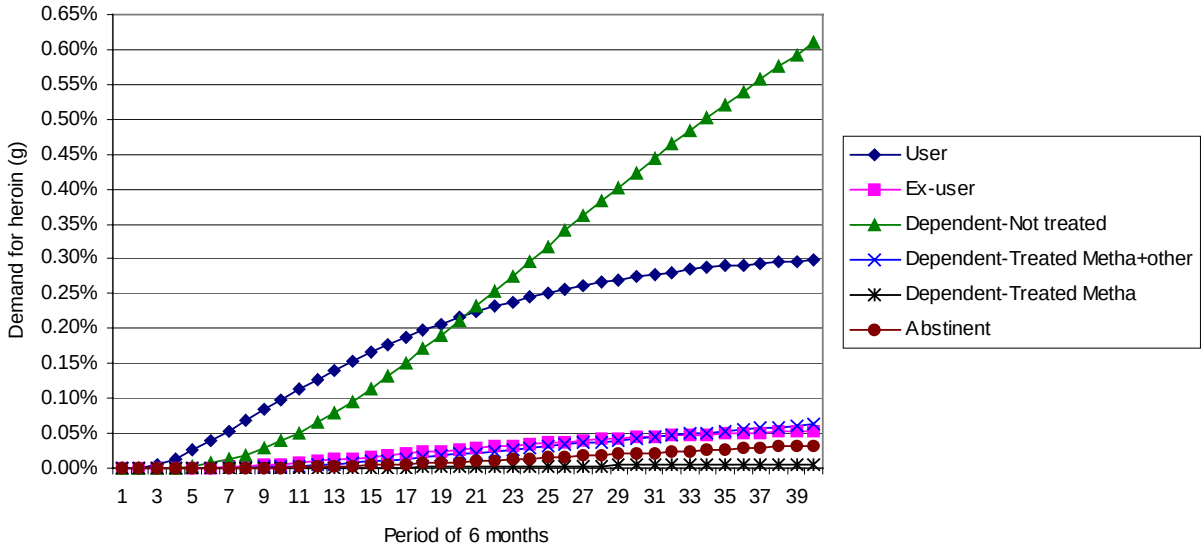
6.3.2. Differences in psychiatric comorbidity

Persons with an ASPD were assumed to act less rationally and therefore less elastic than persons without ASPD. The presence of ASPD is also expected to influence the effect of treatment. However, a number of difficulties hinder to perform analyses for this group separately. First, ASPD may already be present in a person, stimulating heroin use and severity of dependence. On the other hand, it may also well be that the heroin dependence itself enhances ASPD. The latter is intuitively expected to diminish as treatment evolves. Anyway, although many gaps remain to be filled (eg. data on elasticities in a population with and without ASPD), the data that were found in literature were applied into the model in order to identify at least the direction of the effect of ASPD on the basecase results.

Based on Alterman et al. (1998) we assume that persons with ASPD have a 20% higher probability than the general population of aborting methadone treatment, a 14% lower probability of treatment success, and a demand that is 8.5% less elastic towards prices and income.

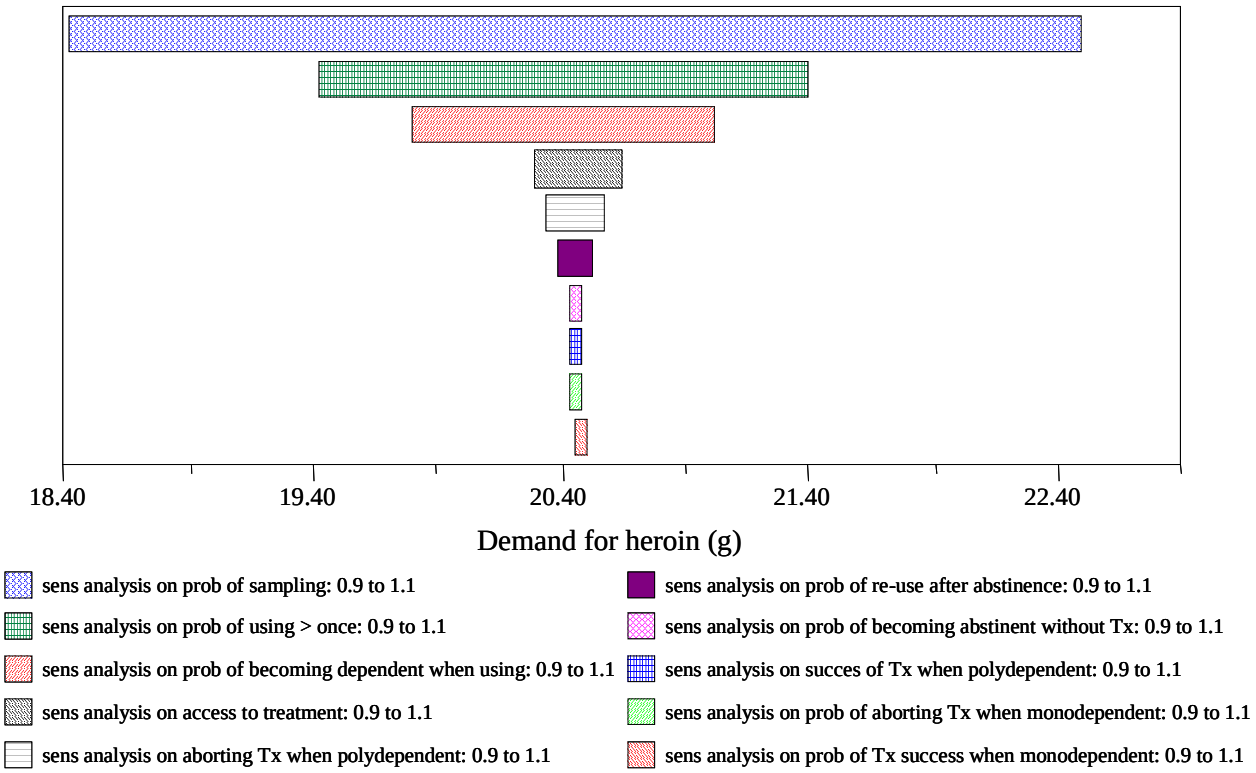
The average evolution of ASPD patients throughout the model is presented in figure 11. When analysing the model, we see an increased total average demand per person of **20.6g** over 20 years in persons with ASPD. Combining both gender and ASPD characteristics in the model shows that **male** heroin users **with an ASPD condition** generate a clearly higher 20-year demand for heroin (**27.5g**) compared to **women (13.8g**). We saw earlier that there are 3 times more men with ASPD than women.

Figure 11: Probability evolution over 20 years for people with ASPD having used heroin more than once.



7. Testing the robustness of the model

In order to test the robustness of the model, a number of transition probabilities were subject to variation. The result of this analysis in presented in figure 12. Some of these variations may overlap the analyses performed earlier in this report. In order to perform these sensitivity analyses, the same methodology as above was applied: each variable was multiplied by a factor, which was set at 1 in the basecase and varied between 0.9 and 1.1 in the sensitivity analyses, representing changes between –10% and +10% of the original value of the variable.



As the graph shows, the most sensitive variable are the probabilities influencing the evolution towards heavier heroin use in the beginning of the process. However, in order to evaluate the question of cost-efficiency, not only the possible result on heroin use should be borne in mind, but also the investment needed to reach such an effect on parameters that influence the demand for heroin.

8. Results on the population level

Chapter 6 calculated the model on a cohort level, resulting in an average demand of 20.45g per person. The current chapter will discuss the results on a population level. This will be done by a bottom-up approach.

According to the OESO (1998) data, there are approximately 86% of people older than 12 years.

In the whole EU, the population consists of about 375 million individuals (EMCDDA 1999).
If 86% of these are considered as the starting cohort, a cumulative demand of heroin over 20 years of 6,595,125 Kg of heroin would be obtained! As a result, the proportional effects of the different proposed measures will be huge.

9. Results taking into account supply side reaction

Chapter 6 provided a general overview of possible measures and their effect on cumulative heroin demand. The most relevant way to interpret the figures is to consider the relative differences in impact between the different measures. Clearly, prevention by avoiding people to try (sample) heroin would be by far most effective, together with price increases, the latter however, more difficult to achieve.

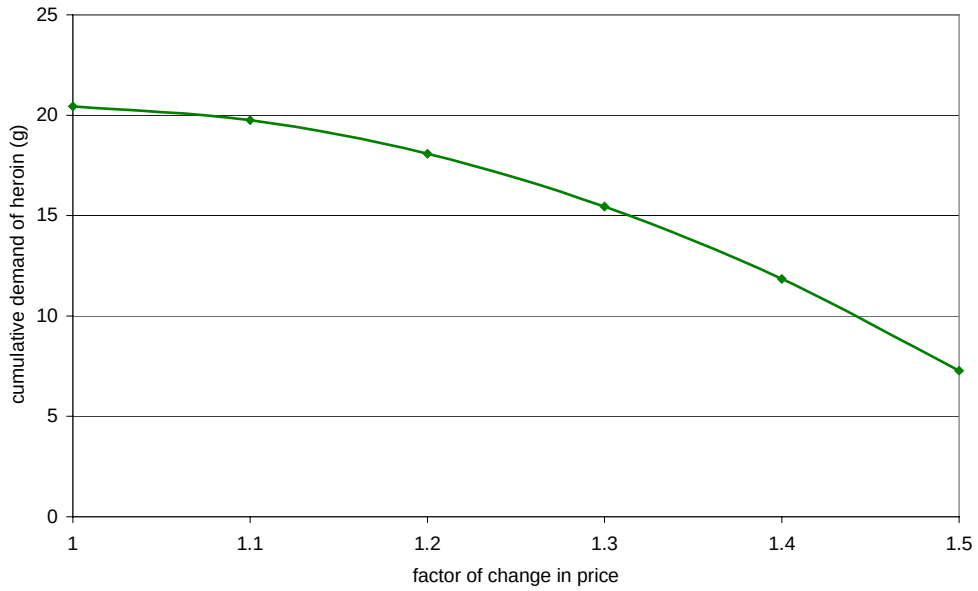
The analyses in chapter 6 were based on a prevalent cohort that was followed over a period of 20 years. It should be noted that each year there is an incident cohort of people becoming 12 years that would join the general cohort and participate in the same career scenario. This was not modelled in but would not change the relative importance of the outcomes.
More importantly, the scenarios in Chapter 6 do consider the "pure" effect on demand, i.e. free of supply reactions. Again, for the purposes of assessing the relative performance of policy measures, this is not a disadvantage. Yet, the effect of supply may strongly change the *absolute* impact of measures, an information that is important to know in the assessment of the cost-effectiveness of policy measures.

Therefore, in an additional analysis, we added to the model the possibility of an impact of demand on prices, and on supply. To illustrate the effect of this, we recalculated the effect of a price change (figure 3) but this time taking into account the possible effect of a decreased demand on price and supply.

We assume thereby that a x % price increase leading to a decrease in demand will result in an immediate supply reaction of x/10 % price decrease, due to competition of suppliers. For instance, a price increase of 50% would lead to a 50/10 = 5% price decrease due to a reaction of suppliers. Moreover, we assume that supply will become more aggressive towards potential samplers, and

increase the probability of sampling by x/2%. For instance, if prices increase by 50%, the probability of sampling will be increased by 25% due to a more aggressive supply side strategy.
As a result, the following graph shows the effect of a price increase of 50% (at value 1.5 on the X-axis) at 10 years (compare with right part of figure 3):

Figure 12: Impact of different heroin price interventions at year 10, taking into account a supply reaction (see text)



The figure shows that clearly a less dramatic total demand decrease is obtained. Still, despite this difference with the “pure demand approach” the conclusions of Chapter 6 remain valid.

10. Additional analyses

The value of determinants of the demand for heroin differ typically between countries in the European Union. The objective of the current general set-up of the model was to make it general; i.e. applicable in different countries provided that country-specific characteristics are entered into the model. In this chapter, some of these parameters that may vary according to the country the model applies to, are varied and their impact on the results is discussed.

In order to be able to put in perspective the results of the extra analyses below against the basecase result, the basecase probabilities and assumptions will be repeated here for the different states of the model. The variables that are varied in the extra analyses below are in ***bold italic***.

General population:
- ***6-month sampling rate: 0.06%***
- 6-month death rate: 0.47%

Has sampled:
- 6-month probability to use heroin more than once: 8.9%
- 6-month death rate: 0.47%
- ***Demanded quantity of heroin(one time): 1g***
- No elasticity towards price nor income

User:
- 6-month probability to become dependent: 15.70%
- 6-month probability to become an ex-user: 2.70%
- 6-month death rate: 0.98%
- Price-elasticity: -3.07 towards the price of heroin
- Income-elasticity: 1.15

Ex-user:
- 6-month probability to re-use heroin: 13.0%
- 6-month death rate: 0.98%

Dependent-Not treated:
- 6-month probability to enter treatment: 8.60%
- 6-month probability to stop heavy use without treatment: 0.72%
- 6-month death rate: 3.70%
- ***Demanded quantity of heroin: 1g/day***
- Price-elasticity: -1.61 towards the price of heroin
- Income-elasticity: 0.60

Dependent-Methadone-treated + other drug use:
- 6-month probability of abstinence: 28.0%
- 6-month retention rate: 61.20%
- 6-month probability of aborting the program: 38.80%
- Proportion in the program with continued use of heroin: 68.60%
- 6-month death rate: 0.98%
- Price-elasticity: -1.61 towards the price of heroin
- Income-elasticity: 0.60

Dependent-Methadone-treated:
- 6-month probability of abstinence: 42.0%
- 6-month retention rate: 61.20%
- 6-month death rate: 0.98%
- Price-elasticity: -3.07 towards the price of heroin
- Income-elasticity: 1.15

Abstinent:
- 6-month probability of lapsing occasionally: 13.0%
- 6-month probability of becoming dependent again: 50.0%
- 6-month death rate: 0.98%

Objective determinants of heroin demand:
- ***Price of heroin: 35 Euro/g***
- Income: 7820 Euro per 6 months, with a yearly increase of 2%

10.1. New European survey data

New survey data on the prevalence of heroin use in European countries were recently made available by the EMCDDA. The main results of these surveys are presented in table 8, together with the median age per country. These data allowed us to calculate a 6-month incidence of trying heroin in the same manner as was done based on (US) data from Van Etten et al. (1999) in section 5.4.1.

Table 8: Analysed age group and lifetime prevalence rates of heroin use (Source: EMCDDA, 2001), and median age (Source: OECD Health data 1998) in different European countries.

Country	Age group	Lifetime prevalence	Median age
Denmark	15-64	0.40%	38
France	15-64	0.40%	37
Greece	15-64	0.40%	38
Ireland	15-64	0.30%	31
Luxembourg	15-64	1.60%	37
Spain	15-64	0.40%	36
The Netherlands	15-64	0.30%	36
Average		**0.54%**	**36.1**

Knowing that the median age is on average 36.1 years, the incidence rate per 6 months can again be calculated by applying the risk-to-rate formula, translating a 21.1-year (36.1-15 (starting age of investigated groups in table 8)) risk (0.54%) into a 6-month incidence. The result of this calculation is a 6-month incidence rate of sampling in the general population of 0.00013 (0.013%). This is lower than what was found with the calculations based on Van Etten et al. (1999) (0.0003) and much lower than the current basecase of the model (0.0006).

Calculating the model, entering a sampling probability of only 0.00013 for the general population, a 20-year demand per person of 3.43g is obtained, which is much lower than the basecase and seems to be an underestimation.

In the basecase analysis, a control "backwards" calculation was performed based on earlier reported EMCDDA data (1999), and an average was calculated of the obtained result (6-month sampling incidence of 0.00085) with the result based on Van Etten et al. (1999). Since we believe the above rate (0.00013) is an underestimation due to underreporting, and the population considered in our model is an European population, the same will be done here: an average rate was calculated based on a rate of 0.54% which was believed to be an underestimation, and a rate of 1%, considered as an upper estimate. This results in a sampling probability for the general population of 0.0005.

Entering this probability into the model would result in a demand of approximately **17.06g** per person over 20 years.

10.2. A smaller demand at sampling

In our basecase model, the one-time demand of a sampler was set at 1g. A panel of experts decided that this was a maximum, and that the real demand at sampling may probably lie around 0.25g.

The resulting 20-year demand per person for heroin due to this change, and taking the sampling rate of 0.0005 as described in section 10.1. into account, comes down to **16.95g**.

Note that the additional analyses following below will account for a sampling demand of 0.25g of heroin instead of 1g. Moreover, the sampling rate in the general population will be held at 0.0005 in all the following analyses, since this was based on European data only, while the basecase involved US data.

10.3. A varying price for heroin

In the basecase model, the price of heroin was set at 35 Euro. This price was based on the National Reports of the BIRN (Belgian Reitox Network) on drugs (1999) and are in fact Belgian prices for 1998. The price of heroin may typically vary among countries in the European Union. Therefore, a sensitivity analysis was performed, varying this price from 35 Euro per gram of heroin to 100 Euro. Table 9 shows the effect of these different prices on the demand. It seems that the 20-year demand per person varies between 16.95g and 5.96g. Note that the basecase result (20.45g) lies not within this range, since the basecase was calculated with a sampling rate of 0.0006 in the general population, and a higher demand for samplers (1g), while here, the model was calculated taking a sampling rate of 0.0005 and a sampler demand of 0.25g into account.

Table 9: Effect of different prices on the demand of heroin (sampling rate=0.0005; sampler demand=0.25g)

Price of heroin	Demand
35	16.95g
40	14.83g
45	13.19g
50	11.87g
55	10.80g
60	9.90g
65	9.14g
70	8.49g
75	7.93g
80	7.43g
85	7.00g
90	6.61g
95	6.27g
100	5.96g

The table shows that increasing prices are accompanied by lower demands. This is mainly due to the fact that the income remained constant in this sensitivity analysis. This is an expression of the economic law that increasing prices cause lower demands - all other variables remaining constant.

10.4. A varying demand for dependent – not treated

Based on a study by Sees et al. (2000), the demand for heroin by a person dependent and not treated for this addiction was set at 1g per day. Via expert opinion, it was determined that this would make that this type of consumer would spend 80% of the available income to heroin.

Since this group of consumers provides the largest proportion of the demand, the effect of variations in this demand on the results will be analysed (taking a sample rate of 0.0005 (10.1.) and a demanded sampling quantity of 0.25g (10.2.) into account). Therefore, the demand of a dependent – not treated consumer was varied between 0.5 and 1g daily. This means practically in the model that, all other variables remaining constant, the proportion of the income spent on heroin will be varied between 40% and 80%. Table 10 shows the analysed daily consumption of a dependent – not treated consumer, the corresponding proportion of the income that is hereby spent on heroin, and the resulting demand for the population.

Table 10: Effect on the result of a varying demand of a dependent – not treated consumer

Daily consumption by dependent – not treated	Proportion of income for heroin	20-year demand
0.5g	0.40	9.58g
0.6g	0.48	11.06g
0.7g	0.56	12.53g
0.8g	0.64	14.00g
0.9g	0.72	15.47g
1g	0.80	16.95g

Table 10 shows that indeed the demand of the group dependent – not treated generates a large impact on the total demand for heroin in the general population over 20 years. When daily consumption is diminished with 50% (from 1g to 0.5g), the total demand decreases with 43.45%.

10.5. Additional Analysis on the population level

Sections 10.2. to 10.4. show that changing different parameters of the model varies the 20-year heroin demand between 5.96g and 16.95g per person. Our basecase result was higher (20.45g) because in the basecase, a higher sampling rate in the general population (0.0006 per 6 months) and a higher demand for samplers (1g) were taken into account. Expert opinion and availability of new European data showed that these figures were probably an overestimation, and therefore, in all above extra analyses, the model has been calculated with a sampling rate of 0.0005 per 6 months, and a sampler demand of 0.25g.

Recalculation towards a population level using the bottom-up approach, and knowing from section 8 that 86% of 375 million people in Europe are our starting cohort, the European demand for heroin then varies between 1,922,100Kg and 5,466,400Kg.

10.6. Analysis for a cross-sectional cohort

In our basecase, the model allows to estimate the amount of heroin demanded by a theoretical cohort of a population > 12 years old over a period of 20 years. Our starting cohort was not cross-sectional, in that it was assumed that everyone entering the model enters at the health state "Non-user", meaning that there is and was no heroin use in the present nor past by the person entering the model. Future use may or may not occur, depending on the incidence-based probabilities at each health state in the model.

It is estimated that the population is cross-sectional according to the current situation in Europe at year 10. The proportion of people being in each health state at year 10 is presented in table 11. The total heroin demand per person in the general population at year 10 is 2.97g. Table 11 additionally shows the cross-section of the population at year 11. The total heroin demand by year 11 had increased to 3.41g per person, an increase by 0.44g. Note that this is a calculation taking into account a sampling rate of 0.0005 per 6 months, a demanded quantity at sampling of 0.25g, a heroin price of 35 Euro per gram, and a demanded quantity of 0.5g daily for a dependent-Not treated heroin user.

Table 11: cross-section of the population in the different health states at year 10 and year 11, with the corresponding total heroin demand per person.

	Year 10	**Year 11**	**Difference**
General population	0.90098	0.8963	-0.00468
Sampler	0.0043	0.00435	0.00005
User	0.00187	0.00194	0.00007
Ex-user	0.00024	0.00026	0.00002
Dependent-Not treated	0.00192	0.00209	0.00017
Dependent-Treated metha+other drugs	0.00019	0.00021	0.00002
Dependent-Treated metha	0.00002	0.00002	0.00000
Abstinent	0.0001	0.00011	0.00001
Death	0.09038	0.09473	0.00435
Heroin demand	*1.78*	*2.31*	*0.53*

The above analyses in sections 10.1. to 10.4. showed that changes in the price of heroin caused the most variability in the results. In order to calculate a range on the cross-sectional results, the demand at year 11 was recalculated, entering a heroin price of 100 Euro per gram into the model as from year 10. The total heroin demand per person in the general population at year 11 is then **1.97g**. This shows that a price increase has a rather modest impact on the demand in the short term.

On a population level, the above generates a demand of 574,050Kg at year 10 and 744,975 at year 11, while the demand at year 11 with 100 Euro per gram as from year 10 was 635,325Kg.

11. Discussion

This report illustrates a macro-economic model to simulate the career of a potential heroin addict. Different data were entered into the model and in this way, the average demand for heroin in a cohort >12 years was estimated over a period of 20 years. The used modelling technique was that of a Markov model.

The creation of the model was performed mainly on epidemiological observational data, within a background of the rational addiction theory of Becker and Murphy (1988), taking into account some modifications to this model as suggested or investigated empirically by different authors.

The model was first calculated for a cohort and thereafter, the calculation was made on a European population level. The primary result was an average demand for heroin in the general population >12 years of 20.45 grams per person, and 6,595,125 Kg on a population level over 20 years.

The impact of different measures on this demand was tested in this model. First, the impact of different price levels was tested. Therefore, a theoretical price increase at year 10 was varied between 0 and 50%. A 50% increase in the price level caused hereby an important reduction in heroin demand of 72% over 20 years.

Variations in income seemed to have a far more modest impact on the demand. In the basecase, a continuous income growth of 1% was built in the model. When entering a growth of 2% per 6 months, the heroin demand per average individual was influenced by less than 1 gram over 20 years.

Another tested scenario was the impact of a better access to methadone treatment. The effect of increasing the access up to 50% easier was tested, generating a decrease of 3.7% in heroin demand. The effect of a higher success rate of substitution treatment was very modest: increasing the treatment success by 30% lowered the heroin demand by 0.2%.

Although Van Etten et al. (1999) found in extensive research that differences between males and females come down to the fact that males have more opportunities for trying heroin and drugs in general than females, the hypothesis of differences between men and women were tested in running the model for both genders separately, showing a higher 20-year demand for men of 27.3 grams versus 13.7 grams for women.

Persons with an ASPD were assumed to act less rational and therefore less elastic than persons without ASPD, and generated a total demand of 20.6 grams per person. The presence of ASPD is also expected to influence the effect of treatment. However, a number of difficulties hinder to perform analyses for this group separately. First, ASPD may already be present in a person, stimulating heroin use and severity of dependence. On the other hand, it may also well be that the heroin dependence itself enhances ASPD. The latter is intuitively expected to diminish as treatment evolves. Anyway, although many gaps remain to be filled (eg. data on elasticities in a

population with and without ASPD), the data that were found in literature were applied into the model in order to identify at least the direction of the effect of ASPD on the basecase results.

A measure that generates a large effect on the demand side of heroin is prevention. The effect of prevention can be measured by the change in the probability of sampling. This variable has been varied between –50% and +50% of its basecase value, showing an almost equal effect on heroin demand. Hence, the model shows that affecting the rate of sampling is one of the most performing intervention for influencing total heroin demand.

Some elements were not investigated with the model. The effect of a decreased tolerance by law and order towards heroin use is complex to analyse. This measure is expected to generate an aversion towards trying or using heroin due to the fear of "getting caught" and ending up in prison. On the other hand, the prevalence of heroin use would lie between 15 and 50% among prisoners (EMCDDA, 1999). This makes the question rise of whether prison has a stimulating effect on heroin use rather than the inverse. However, apparently substitution programs and other measures would gain access in prisons lately (EMCDDA, 1999). There is consequently a net effect of law enforcement, and very few data are available on this topic. Therefore, our model could not be programmed separately in function of this measure. The price-increasing effect of law enforcement, however, is important, and was discussed above.

In an additional analysis, we simulated the possible smoothing effects from supply-side reaction. Although a smoothing effect of a measure such as price increase could be observed, this inclusion would not change the relative performance of the different proposed measures.

In order to be able to meet the criterion that the current model was a general model, applicable in different European countries, provided entering country-specific characteristics, some extra analyses were performed and presented in a separate chapter. New European survey data resulted in a lower estimated sampling rate (0.0005) than calculated in the basecase analysis. The resulting demand with this sampling rate would be 17.06g per person per 20 years.

A second recalculation of the model concerned the demanded quantity of heroin by samplers. In the basecase model, this was set at 1g. Hence, the model was additionally analysed entering a demanded quantity of 0.25g by samplers (and holding the 0.0005 sampling rate). The resulting 20-year demanded quantity of heroin for the whole population was 16.95g (instead of 20.45g in the basecase).

Within the same thinking framework, and holding on to a sampling demand of 0.25g and the sampling rate of 0.0005, the price of heroin was varied between 35 and 100 Euro per gram, generating a 20-year demand varying between 16.95g and 5.96g respectively.

Since the group of dependent – not treated consumers provides the largest proportion of the demand, the effect of variations in this demand on the results were analysed. Therefore, the

demand of a dependent – not treated consumer was varied between 0.5 and 1g daily. The effect on total heroin demand was as follows: with a consumption of 0.5g per day for a dependent – not treated, total demand came down to 9.58g per person for 20 years, compared to 16.95g per person for 1g daily.

Recalculation of these extra analyses towards a population level, with a sampling rate of 0.0005 and a sampler demand of 0.25g, showed that the 20-year European demand for heroin then varies between 1,922,100Kg and 5,466,375Kg.

Our model started with a closed cohort of non-users > 12 years old. It is estimated that the population is cross-sectional according to the current situation in Europe at year 10. The total heroin demand per person in the general population at year 10 (with a sampling rate of 0.0005 per 6 months, a sampling demand of 0.25g, a dependent-not treated demand of 0.5g daily, a heroin price of 35 Euros per gram) is 1.78g. Considering this population, a short-term analysis was performed over 1 year. The total heroin demand by year 11 had increased to 2.31g per person, an increase by 0.53g. Analyzing the effect of price changes in this short term showed that a price increase from 35 Euro/g up to 100 Euro/g as from year 10 would have a rather modest impact on the short term demand – a demand of 1.97g per person was obtained, i.e. a difference of 0.34g per individual. On a population level, however, the above generates a difference of 109,650Kg in 1 year, which is considerable.

Finally, since for a variety of figures, no straightforward data could be found directly in literature, expert opinion was required. We believe that in a first step, it would be useful for the model's probabilities, to be reviewed and/or validated by a panel of experts. In the future, epidemiological research may focus on such variables, in order to better populate the predictive model, and hence to better estimate the impact of interventions in the market.

Definitions

Item	Definition
Budget constraint	The amount of goods that can be purchased of a good at given prices is restrained with the available budget. The available budget is a function of the value of available assets and the revenues for a given period.
Complements	When a change in the parameters leads to a decreasing (increasing) demand of good A and an decreasing (increasing) demand for good B, then good B is a complement to good A (like bread and butter).
Concave	curved inwards, like the inside surface of a hollow ball
Consumption capital	A measure for the current "load" of past consumption of addictive goods and life events.
Convex	curved outwards, like the surface of an eye
Cross-price elasticity	Quantifies how the price of one good affects the demand for another.
Depreciation rate	A rate that expresses the gradual loss of (money) value of a good as time progresses.
Discounting	The mathematical process that takes the time preference of individuals into account.
Elastic	A demand is elastic when a certain proportional change in a parameter leads towards a proportionally larger change in the demand for a certain good.
Elasticity	A measure for the sensitivity of the demand for a certain good towards changes in the parameters of the model, eg. the price
Income elasticity	Quantifies how changes in income affect the demand for a certain good
Independent goods	When a change in the parameters leads to a decreasing (increasing) demand of good A, but the demand for B remains unchanged, then good A and B are independent goods (like cars and butter).
Inelastic	A demand is inelastic when a certain proportional change in a parameter leads towards a proportionally smaller change in the demand for a certain good.
Marginal utility	The extra utility that is obtained following a change in one of the parameters of the model.
Rational behaviour	Rational behaviour implies that four conditions are fulfilled: (1) An individual takes all feasible actions into consideration; (2) all available information is taken into account in order to determine the consequences of each action as meticulous as possible; (3) Each individual has well defined preferences about all potential consequences; and (4) He chooses the action with the most wanted consequences.
Steady state	A state of equilibrium; where the demand for a good generates the highest possible utility under given parameters.
Substitutes	When a change in the parameters leads to a decreasing demand of good A and an increasing demand for good B, then good B is a substitute for good A (like meat and fish).
Time preference	The preference of an individual to dispose of a certain amount/reward now instead of later in time. The time preference is expressed by a rate. The higher the preference for current times, the higher time preference rate.

References

Ainslie G., Picoeconomics. Cambridge University Press. 1992. In: Bretteville-Jensen A.L., Addiction and discounting, Journal of Health Economics. 1999, 18, pp. 393-407.

Alterman AI, Kampman K, Boardman CR, Cacciola JS, Rutherford MJ, Mc Kay JR, Maany I., Prediction of atrition from day hospital treatment in lower socioeconomic cocaine dependent men. Drug and alcohol dependence. 1997, 46, pp. 79-85.

Alterman et al., Prediction of 7 months methadone maintenance treatment response by four measures of antisociality, Drug and Alcohol Dependence. 1998, 49, pp. 217-223.

APA American Psychiatric Association. Diagnostic and statistical manual of mental disorders, 4th edn. Washington, 1994.

Avants SK, Margolin A, Kosten TR, Rounsaville BJ, Schottenfeld RS. When Is Less Treatment Better. The Role of Social Anxiety in Matching Methadone Patients to Psychosocial Treatments, Journal of consulting and clinical psychology. 1998, 66(6), pp. 924-931.

Azalos R, McDuff DR, Weintraub E, Montoya I Schwartz R, Engaging hospitalized heroin dependent patients into substance abuse treatment. Journal of substance abuse treatment. 1999, 17, pp. 149-58.

Azarin NH, Holz WC (1966) Punishment. In W Honing (Ed.) Operant behavior; areas of research and application. NY: Appleton-Centurt-Crofts.

Ball JC, Ross A, The effectiveness of methadone maintenance treament, NY, Springer-Verlag. 1991.

Becker G.S. and C.B. Mulligan, The endogenous determination of time preference, The Quarterly Journal of Economics. 1997, 112 (3), pp. 729-758. In: Bretteville-Jensen A.L., Addiction and discounting, Journal of Health Economics. 1999, 18, pp. 393-407.

Becker G.S. and K.M. Murphy, A theory of rational addiction, Journal of Political Economy. 1988, Vol 96 (4), pp. 675–700.

Becker G.S. et al., Economics of drugs. Rational addiction and the effect of price on consumption, AEA Papers and Proceedings. 1991, Vol 81 (2), pp. 237-241.

Bickel W.K. et al., The price of change. The behavioral economics of drug dependence. Behavior Therapy. 1998, 29 (4), pp. 545-565.

Bickel WK, DeGrandpre RJ, Higgins ST, Hughes JR. Behavioral economics of drug self-administration. I. Functional equivalence of response requirement and drug dose. Life Sci. 1990;47(17):1501-10.

Blair and Vogel, 1973. In: Kopp P., L'économie de la drogue.

Brooner RK, King VL, Kidorf M, Schmidt CW, Bigelow GE, Psychiatric and substance use comorbidity among treatment-seeking opioid abusers, Archives of general psychiatry. 1997, 54(1), pp. 71-80.

Brown and Silverman, 1974. In: Kopp P., L'économie de la drogue

Brown BS, Watters JK, Inglehart AS Akins C, Methadone maintenance dose levels and program retention., American Journal of drug and alcohol abuse. 1982-1983, 9, pp. 229-39.

Budney AJ, Higgings ST, Wong C, Bickel WK, Early abstinence predicts outcome in behavioral treatment for cocaine dependence. In: harris, LS (Ed.) Problems of drug dependence 1995, Proceedings of the 57th annual scientific meeting, NIDA research monograph. National institute on drug abuse. Rockville, MD, 1996.

Chatham LR, Hiller ML, Rowanszal GA, Simpson DD. Gender Differences at Admission and follow-up in a Sample of Methadone-Maintenance Clients, SUBSTANCE USE AND MISUSE. 1999, 34(8), pp. 1137-1165.

Chilcoat H, Anthony J , Impact of parent monitoring on the initiation of drug use through late childhood. Journal of the American Academy of child and adolescent Psychiatry. 1996, 35, pp. 91-100.

Chilcoat H, Dishion T, Antony J , Parent monitoring and the incidence of drug sampling in urban elementary school children, American journal of epidemiology. 1995, 141, pp. 25-31.

Chilcoat H. and C. Schutz, Racial/ethnical and age differences in crack use within neighborhoods, Addiction Research. 1995, 3, pp. 103-111.

Crum R, Lillie-Blanton M, Anthony J, Neighborhood environment and opportunity to use cocaine in late childhood and early adolescence, Drug and alcohol dependence. 1996, 43,155-161.

De Jesus AA, Umbricht-scneiter A, Hawkins W, Preston KL, Gender differences in methadone maintenance patients, Annual meeting of the college of problems of drug dependence. Inc, Nashville, TN, 1997.

DOWN: Drugs and alcohol Women's network. When a crèche is not enough. A survey of drug and alcohol services for women. London: Drug and alcohol Women's network, Glass, 1994.

Elmer GI, Miner L, Pickens RW. Genetic contributions to drug abuse. Cocaine abuse, behavior, pharmacology,and clinical applications. Edit Higgins ST and Katz JL academic press 1998. Pp 305.

EMCDDA - Survey data on drug use in European countries, 2001.

Gafni, A., Birch, S. Preferences for outcomes in economic evaluation: an economic approach to addressing economic problems. *Social Science and Medicine* 1995; **40 (6)**: 767-776.

Grapendaal M. et al., A world of opportunities: lifestyle and economic behaviour of heroin addicts in Amsterdam. New York: State University of New York Press. 1993. In: Brettevilde-
Jensen A.L., Gender, heroin consumption and economic behaviour, Health Economics. 1999, 8, pp. 379 – 389.

Greenfield L, Brady JV, Besteman KJ, De Smet A. Patient retention in mobile and fixed-site methadone maintenance treatment. Drug Alcohol Depend. 1996 Oct;42(2):125-31.

Grella CE, Anglin D Wugalter SE, Rawson R, Hasson A, Reasons for discharge from methadone maintenance for addicts at high risk of HIV infection or transmission, Journal of psychoactive drugs. 1994, 26, pp. 223-232.

Gronbladh et al., Mortality in heroin addiction: impact of methadone treatment, Acta Psychiatr Scand. 1990, 82, pp. 223-227. In: Zanis D. and G. Woody, One-year mortality rates following methadone treatment discharge, Drug and Alcohol Dependence. 1998, 52, pp. 257-260.

Grossman M. and F.J. Chaloupka, The demand for cocaine by young adults: a rational addiction approach, Journal of Health Economics. 1998, 17, pp. 427-474

Hadreas J. and J. Roumasset, 1977. In: Kopp P., L’économie de la drogue.

Hawkins JD, Catalano RF, Miller JY (1992). Risk and protective factors for alcohol and other drug problems in adolecence and early adulthood: implications for substance abuse prevention. Psychological bulletin, 112, 64-105.

Hunter GM and A. Judd, Women Injecting Drug-Users in London. The Extent and Nature of Their Contact with Drug and Health-Services, Drug and alcohol review. 1998, 17(3), pp. 267-276.

Hyten C. et al., Exchange delays and impulsive choice in adult humans, Journal of the experimental analysis of behaviour. 1994, 62, pp. 225 – 233.

Iguchi MY, Belding MA, Morral AR, Lamb RJ, Husband SD. Reinforcing operants other than abstinence in drug-abuse treatment – An affective alternative for reducing drug-use. Journal of consulting and clinical psychology. 1997, 65(3), pp. 421-428.

Kaplan HI, Sadock BJ.Personality disorders. In Pocket handbook of clinical psychiatry. Edit Williams & Wiliams (1990) pp 161

Kidorf M, Hollander JR, King VL, Brooner RK. Increasing Employment of Opioid Dependent Outpatients. An Intensive Behavioral Intervention, Drug and alcohol dependence. 1998, 50(1), pp. 73-80.

Kopp P., L'économie de la drogue.

Madden G.J. et al., Impulsive and self-control choices in opioid-dependent patients and non-drug using control participants: drug and monetary rewards, Experimental and Clinical Psychopharmacology. 1997, Vol. 5 (No. 3), pp. 256 – 262.

Maddux JF, Desmond DP, Esquivel M. Rapid admission and retention on methadone. Am J Drug Alcohol Abuse. 1995 Nov;21(4):533-47.105

Magura S, Nwakeze PC, Demsky SY, Pre-and in-treatment predictors of retention in methadone treatment using survival analysis, Addiction. 1998, Vol 93 (1), pp. 51-60.

Matheson C, Bond CM, Mollison J. Attitudinal Factors Associated with Community Pharmacists Involvement in Services for Drug Misusers, Addiction. 1999, 94(9), pp. 1349-1359.

McLean AT, Arndt IO, Metzger DS et al, The effects of psychosocial services in substance abuse treatment, JAMA. 1993, 269, pp. 1953-59.

Milby JB, Scumacher JE, Raczynski JM, Caldwell E, Engle M, Carr MM, Sufficient conditions for effective treatment of substance abusing homeless persons. Drug Alcohol Depen. 1996, 43, pp. 39-47.

Monterosso J. and G. Ainslie, Beyond discounting: possible experimental models of impulse control, Psychopharmacology. 1999, 146, pp. 339-347.

Morral AR, Belding MA, Iguchi MY., Identifying methadone maintenance clients at risk for poor treatment responce: pretreatment and early progress indicators, Drug and alcohol dependence. 1999, 55, pp. 25-33.

Morral AR, Iguchi MY, Belding MA,.Lamb JR , Natural classes of treatment response: J consult Clin Psychol. 1997, 65, pp. 673-85.

NHSDA, Office of Applied Studies, Analysis of Substance Abuse and Treatment Need Issues, Department of Health and Human Services, Substance Abuse and Mental Health Service Administration, 1996.

Orphanides A. and D. Zervos, Myopia and addictive behaviour, The Economic Journal. 1998, 108, pp. 75-91.

Pacula R.L., Economic modelling of the gateway effect, Health Economics. 1997, Vol. 6, pp. 521-524.

Pauwels W., Micro-economie (Vomule 1). University of Antwerp (UFSIA), 1999-2000.
Petry N.M. and W.K. Bickel, Polydrug abuse in heroin addicts: a behavioral economic analysis, Addiction. 1998, 93 (3), pp. 321-335.

Regier DA, Farmer ME, Rae DS, Locke BZ, Keith SJ, Judd LL, Goodwin FK. Comorbidity of mental disorders with alcohol and other drug abuse. Results from the Epidemiologic Catchment Area (ECA) Study. JAMA. 1990 Nov 21;264(19):2511-8.

Rossi C. et al., Pilot project to estimate time trends and incidence of problem drug use in the European Union (CT.98.EP.07), European Monitoring Centre for Drugs and Drug Addiction (EMCDDA), March 1999.

Rousanville BJ, Weissman MM, Crits-Christoph K, Wilber C Kleber H., Diagnosis and symptoms of depression in opiate addicts: course and relationship to treatment outcome, Arch Gen Psychiatry. 1982;39, pp. 151-156.

Saxon A, Fleming C, Jackson TR, Wells E, Calsyn DA, Predictors of methadone treatment outcome. NIDA Research monograph Series. 1994, 153, p.143.

Schultz J, Chilcoat H Antony J, Disadvantaged neighborhoods and early initiation of drug use. World psychiatric association, Epidemiology and Community psychiatry. 1993, Groningen, Netherlands.

Sees K. et al., Methadone Maintenance versus 180-day psychosocially enriched detoxification for treatment of opioid dependence. A randomized controlled trial, JAMA. 2000, Vol. 283 (10), pp. 1303-1310.

Seivewright N. and C. Daly, Personality-disorder and drug-use – A review, Drug and Alcohol review. 1997, 16(3), pp. 235-250.

Silverman and Spruill, 1977. In: Kopp P., L'économie de la drogue

Silverman K, Chutuape MA, Bigelow GE, Stitzer ML. Voucher-Based Reinforcement of Cocaine Abstinence in Treatment-Resistant Methadone Patients. Effects of Reinforcement Magnitude. Psychopharmacology. 1999, 146(2), pp.128-138.

Skodol AE, Oldham JM, Gallaher PE. Axis II comorbidity of substance use disorders among patients referred for treatment of personality disorders. Am J Psychiatry. 1999 May;156(5):733-8.

Tyrer P, Seivewright H Studies of outcome. In Tyrer P, ed. Personality disorders: diagnosis, treatment and course. London: Wright, 1988.

Vuchinich R.E. and J.A. Tucker, Choice, Behavioural Economics, and Addictive Behaviour Patterns, Treating addictive behaviours. 1998, 2nd ed., Miller and Heather (eds), Plenum Press, New York.

Wechsberg WM, Craddock GG, Hubard RL, Preliminary Findings: Gender differences among those entering methadone treament, National Methadone conference. Washington DC, 1994.

White and Lusksetich, 1983. In: Kopp P., L'économie de la drogue.

Widman et al., Patterns of service use and treatment involvement of methadone maintenance patients, Journal of Substance Abuse. 1997, Vol 14 (1), pp. 29-35.

Willems JCEW, Iguchi MY, Lidz V, Bux DA., Change in drug-using networks of injecting drug-users during Methadone treatment – A pilot-study using snowball recruitment and intensive interviews, Substance use and misuse. 1997, 32 (11), pp. 1539-1554.

Winston G.C., Addiction and backsliding: a theory of compulsive consumption, Journal of Economic Behaviour and Organisation. 1980, Vol 1, pp. 295-324. In: Orphanides A. and D. Zervos, Myopia and addictive behaviour, The Economic Journal. 1998, 108, pp. 75-91.
Yangita T (1973) An experimental framework for evaluation of dependence liability in various types of drugs in monkeys. Bulletin on narcotics. 25, 57-64.

Zanis D. and G. Woody, One-year mortality rates following methadone treatment discharge, Drug and Alcohol Dependence. 1998, 52, pp. 257-260.

Annex: Markov models

Markov models are often employed to represent random processes that evolve over time. They simulate short-term processes or long-term processes, and a wide variety of outcomes can be calculated. Moreover, Markov models have both predictive and retrospective applications.

The basic Markov model requires that one defines a finite set of states in which an individual can be found. The states must be numerated in such a way that, in any given interval, the individual will be in one state only, no more and no less.

The process of a Markov model is viewed and evaluated at discrete time intervals. The length of this interval, the model's cycle length (in the current model 6 months) is determined by the creator of the model. Any interval may be used, but it must remain fixed for the duration of the calculation, and based on the logic history of the investigated condition.

Between cycles, an individual may move from one state to another, or remain in the same state. Which transitions are possible at the end of the interval will depend on the state the individual has been in during the current interval. Note that, while many transition paths may be available to an individual, only one may be taken at the conclusion of a given interval. Each transition is assigned a probability. The set of transition probabilities for each state must sum to 1.0. A separate set of probabilities must describe the initial distribution of the Markov cohort among the states immediately before the process begins. In our model, all individuals start the model at the state "non-user".

The standard way to analyse a Markov model is using a cohort simulation. A cohort is run through the model and viewed probabilistically.

There is an important limitation to the Markov model, called the Markov property. This means that the behaviour of the process subsequent to any cycle depends only on its description in that cycle. That is, the process has no memory for earlier cycles. For instance, if someone is in the state Dependent-Not treated after cycle n, we know the probability that he or she will end up in the state Death after cycle n+1. It doesn't matter how much time that person spent in other states before becoming Dependent-Not treated. If prognosis does depend on past history, it requires that there is a distinct state to represent different histories.

Another note of caution should be made when calculating transition probabilities for Markov models. The probabilities available in literature may not refer to the same period of time as the one chosen for our Markov cycle. Suppose we found a published probability of death over 5 years as the basis for a death transition probability estimate in a Markov model based on a yearly cycle. We cannot simply estimate the yearly transition probability by dividing the 5-year probability by 5

since this will overestimate of a transition due to the effect of compounding. Instead, we use the "Risk-to-rate formula":

$Rate_{1y} = 1- (1-Risk_{5y})^{1/5}$

Where "$Rate_{1y}$" is our yearly transition probability we wish to estimate and "$Risk_{5y}$" is the overall probability over 5 years.

The analysis of a Markov model with constant transition probabilities can be done by matrix algebra. For a matrix with n states, there will be n^2 transition probabilities, and these can be represented in an n x n matrix. Probabilities representing disallowed transitions will be zero. An example of a transition matrix is presented in the table below, supposing we have a simple Markov model with the states Well, Disabled and Death.

		TO		
		WELL	DISABLED	DEATH
FROM	WELL	0.6	0.2	0.2
	DISABLED	0	0.6	0.4
	DEATH	0	0	1

Presenting a Markov model in a tree, as was done in the current report, has the advantage that the analyst can break up a larger problem into smaller, more manageable ones. The use of subtrees promotes appropriate symmetry among the various states, enhancing the fidelity of the model. The model provides much more flexibilty when changing or refining a Markov model, and the disaggregation of the transition probabilities permits sensitivity analysis to be performed on any component probability.

Being in each state is associated with a certain outcome. In our model, this outcome was the number of grams of heroin, generated while being in that state. When calculating the model, the proportion of people being in a certain state at a certain time will be multiplied by the generated outcome while being in that state. In this way, we can calculate for instance the average grams of heroin, generated by someone running through the model for a time horizon of 20 years.

For more literature on Markov models: Sonnenberg F. and R. Beck, Markov models in medical decision making: A practical guide, Medical Decision Making. 1993, 13, pp. 322-338.

The software we used for development of our model was DATA™ (version 3.5.7) of TreeAge Software Inc.