6. Car Rental Case Study in UML

6.1 Getting Started

- To follow: A medium sized case study for a car rental administration system
- Explanation of central UML diagrams and language features therein
- Used here: Use case, class, object, statechart, sequence, collaboration, and activity diagrams
- Development of the case study also demonstrates a typical development process
- Diagram order in this document does not reflect the order occurring in the development

Overview on the Used Development Process

(1) Start with a use case diagram giving an overview on the system, its boundaries and its main functionality

(2) Develop object diagrams and sequence diagrams as desired scenarios for the system structure and behavior

(3) Develop a class diagram and a statechart diagram for each class; start with a textual description of the statechart diagrams; continue with a more formal description for the statecharts

Overview on the Used Development Process

(4) Check whether the existing object diagrams and sequence diagrams are consistent with the class diagram and the statechart diagrams; if neccessary, modify them

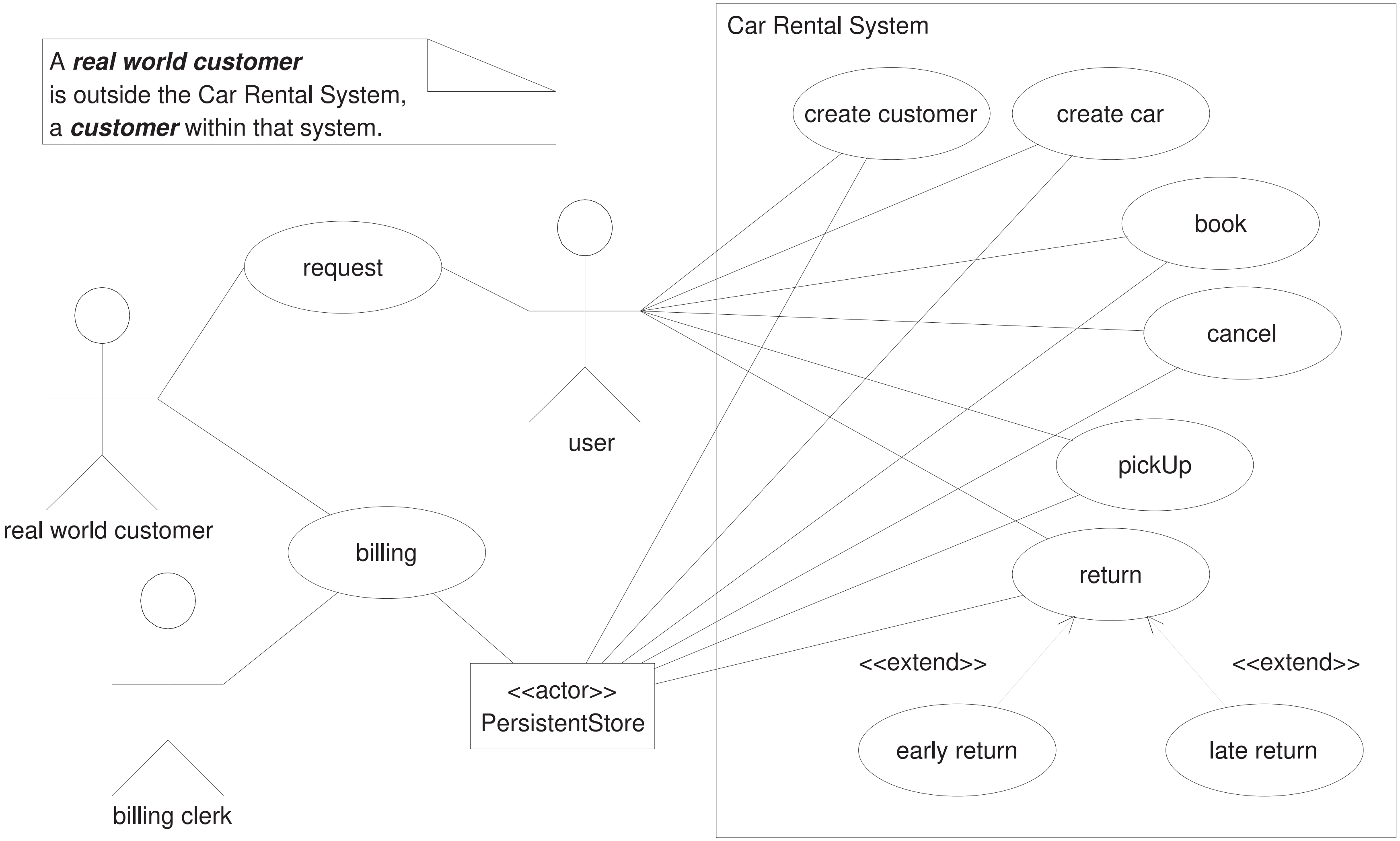
(5) Develop more object and sequence diagrams

(6) If an operations seems to become stable (no changes in the diagrams for the parts with that operation), start to develop activity diagrams for that operation; begin with a textual description and advance to a more formal one

(7) Repeat steps (4)-(6) until an acceptable model is found

6.2 Use Cases

Use Case Diagram



Details for Use Case create customer

```
Use case name: create customer
Goal: to create a new customer
Precondition: the real world customer to be recorded is
 currently not represented
Postcondition: a new customer exists
Actors: user
Triggering event: a real world customer must be recorded
Description: -
Extensions: -
Alternatives: -
```

Details for Use Case create car

```
Use case name: create car
Goal: to create a new car
Precondition: the real world car to be recorded is
 currently not represented
Postcondition: a new car exists
Actors: user
Triggering event: a real world car must be recorded
Description: -
Extensions: -
Alternatives: -
```

Details for Use Case book

```
Use case name: book
Goal: to enter a car rental booking
Precondition: the booking details are plausible
Postcondition: a new booking exists; the booking is
 now an open booking
Actors: user
Triggering event: a real world customer requests a booking
Description: the real world customer wants to rent a real
 world car of a certain category; start day of the rental is
 the current day or a day after the current day; end day of
 the rental lies after the start day
Extensions: -
Alternatives: -
```

Details for Use Case cancel

```
Use case name: cancel
Goal: to prevent that a car must be picked up for a booking
Precondition: the booking to be canceled is present
Postcondition: the booking is marked as closed; no car will
 be picked up for this booking
Actors: user
Triggering event: a real world customer requests a
 cancelation of a booking
Description: –
Extensions: –
Alternatives: triggering event – the start day of a booking
 is passed and no car has been picked up by the customer for
 that booking
```

Details for Use Case pickUp

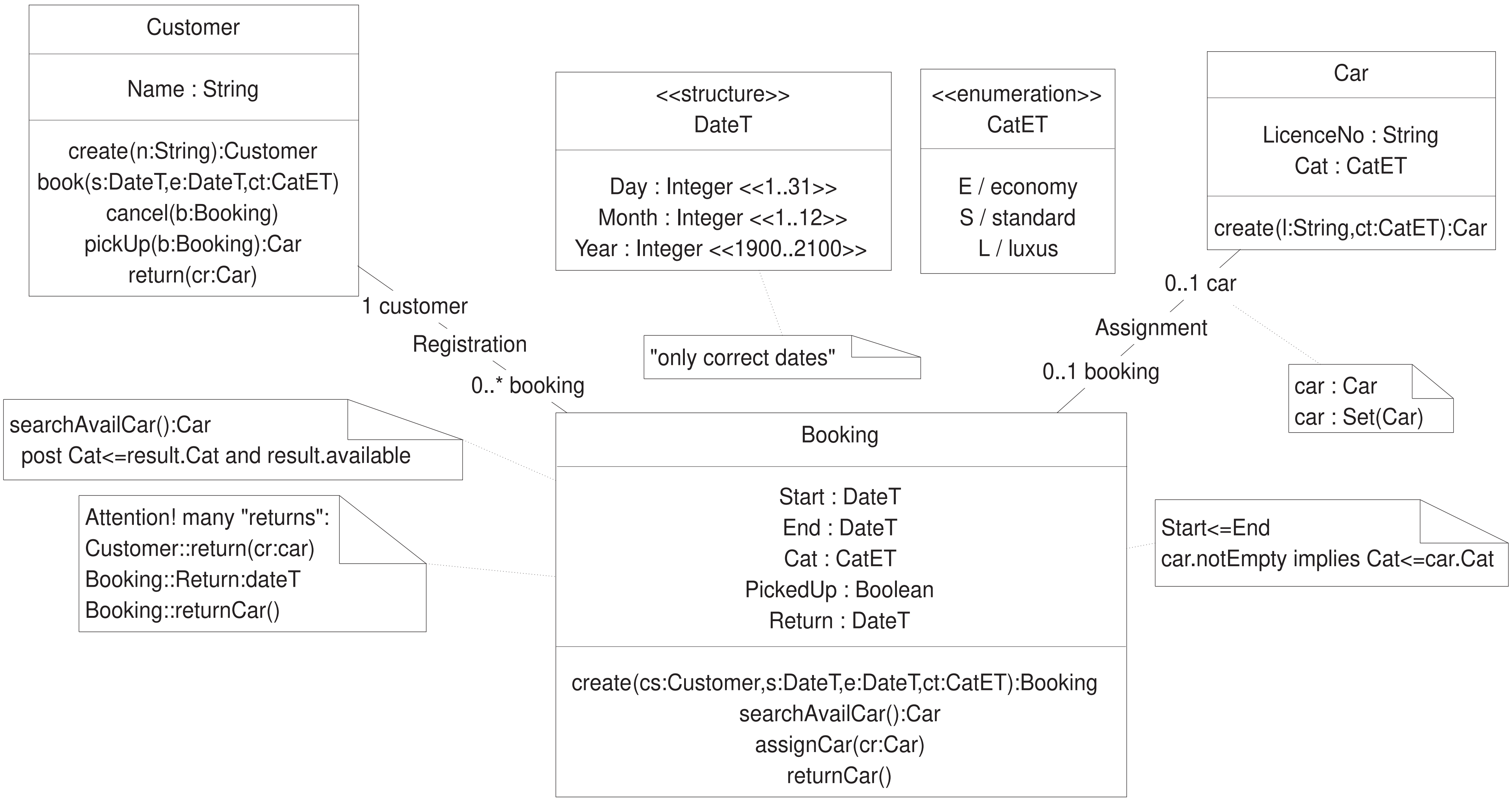
```
Use case name: pickUp
Goal: to deliver a car for a car rental
Precondition: a booking is present
Postcondition: a suitable car is marked as unavailable (a
 real world car is given to a real world customer); the
 booking becomes a current booking
Actors: user
Triggering event: a real world customer requests a pick up
Description: a suitable car must be found among the
 currently available cars; if none is present, a new car may
 be added (a new real world car is purchased)
Extensions: -
Alternatives: -
```

Details for Use Case return

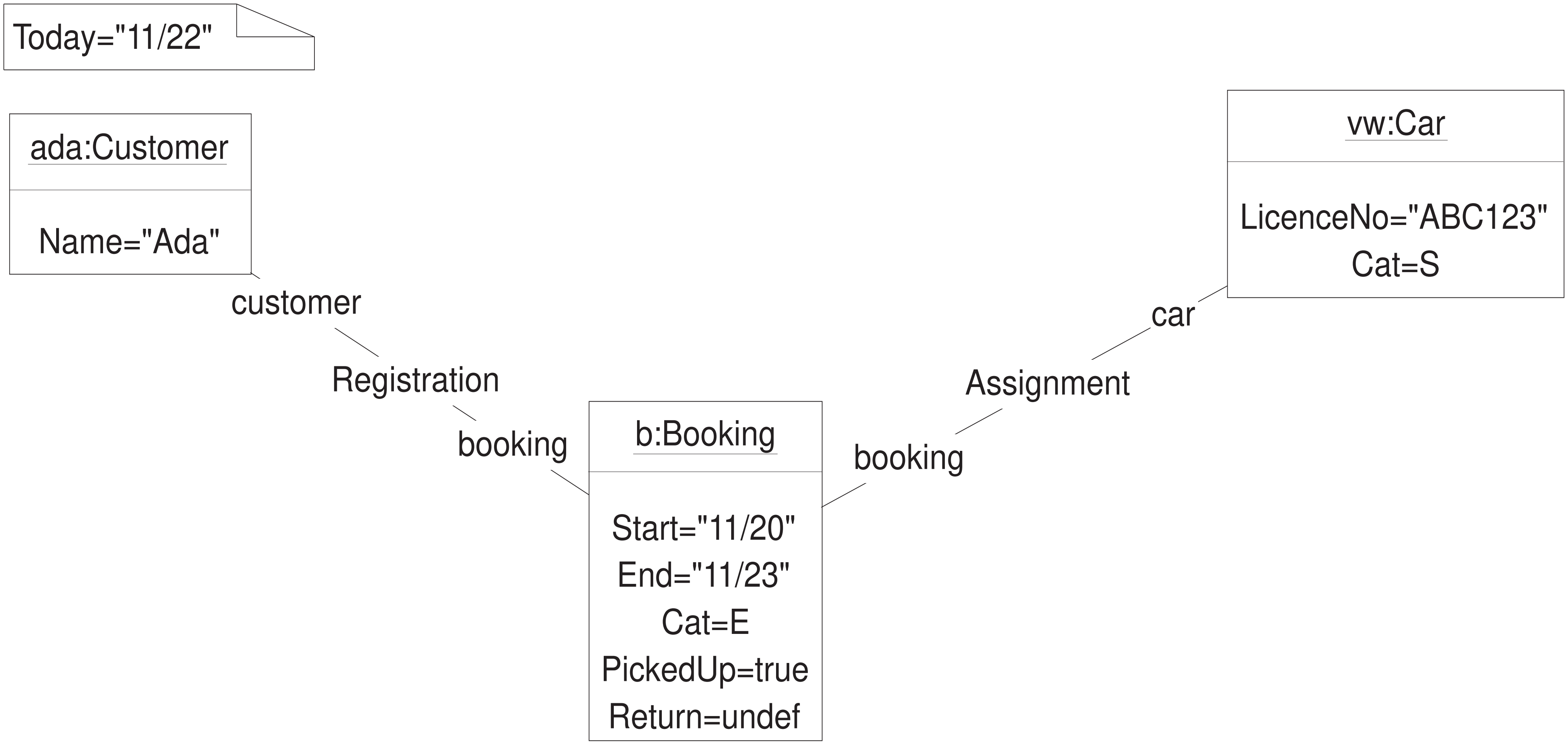
```
Use case name: return
Goal: to return a car for a car rental
Precondition: a current booking exists and a car has been
 delivered
Postcondition: the booking becomes closed; the car becomes
 available (real world customer has returned real world car)
Actors: user
Triggering event: a real world customer requests a return on
 the end day of the booking
Description: -
Extensions:
 early return: a rented car is returned before the end date
  of the booking
 late return: a rented car is returned after the end date of
  the booking
Alternatives: -
```

6.3 Static Structure Diagrams

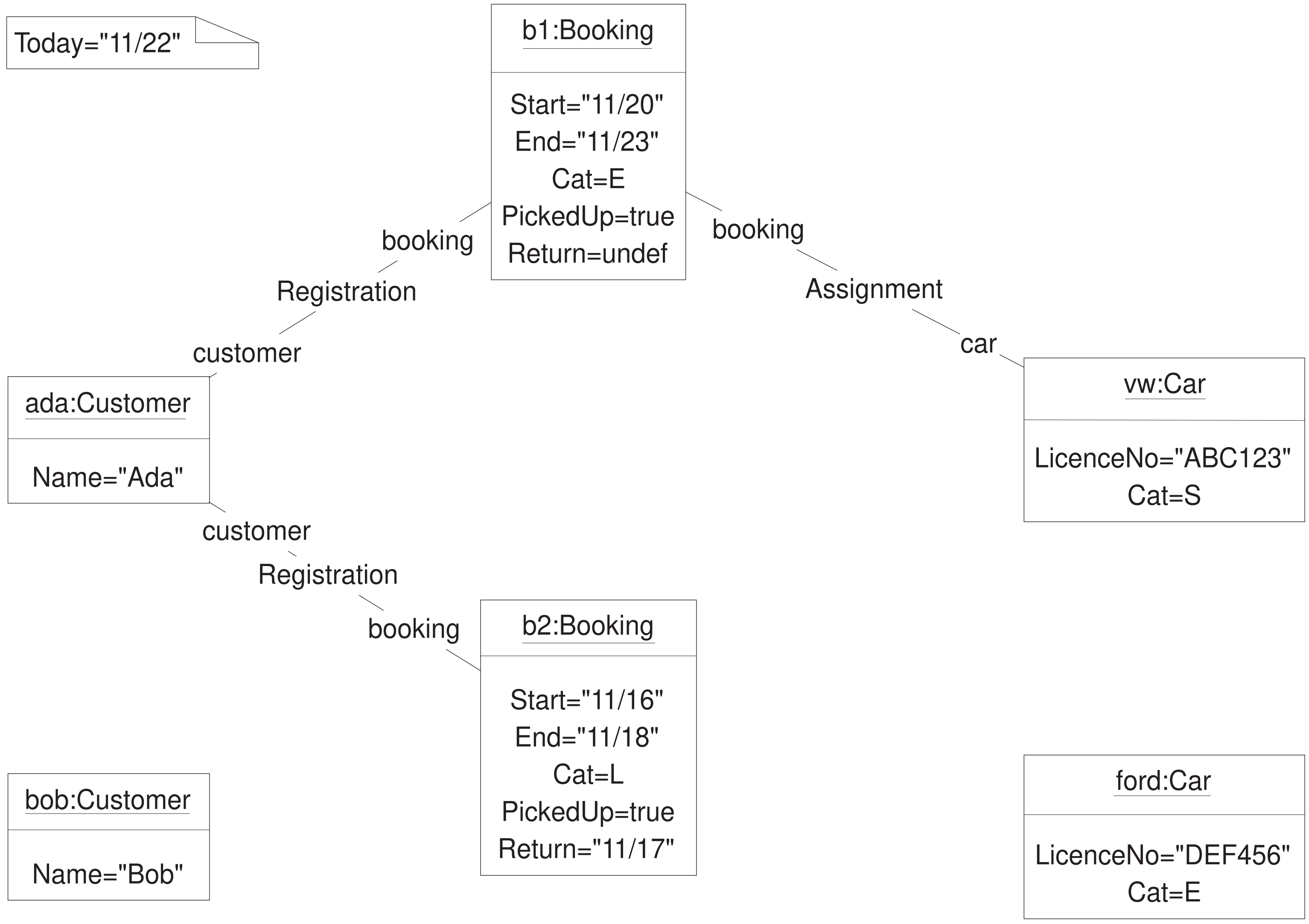
Class Diagram



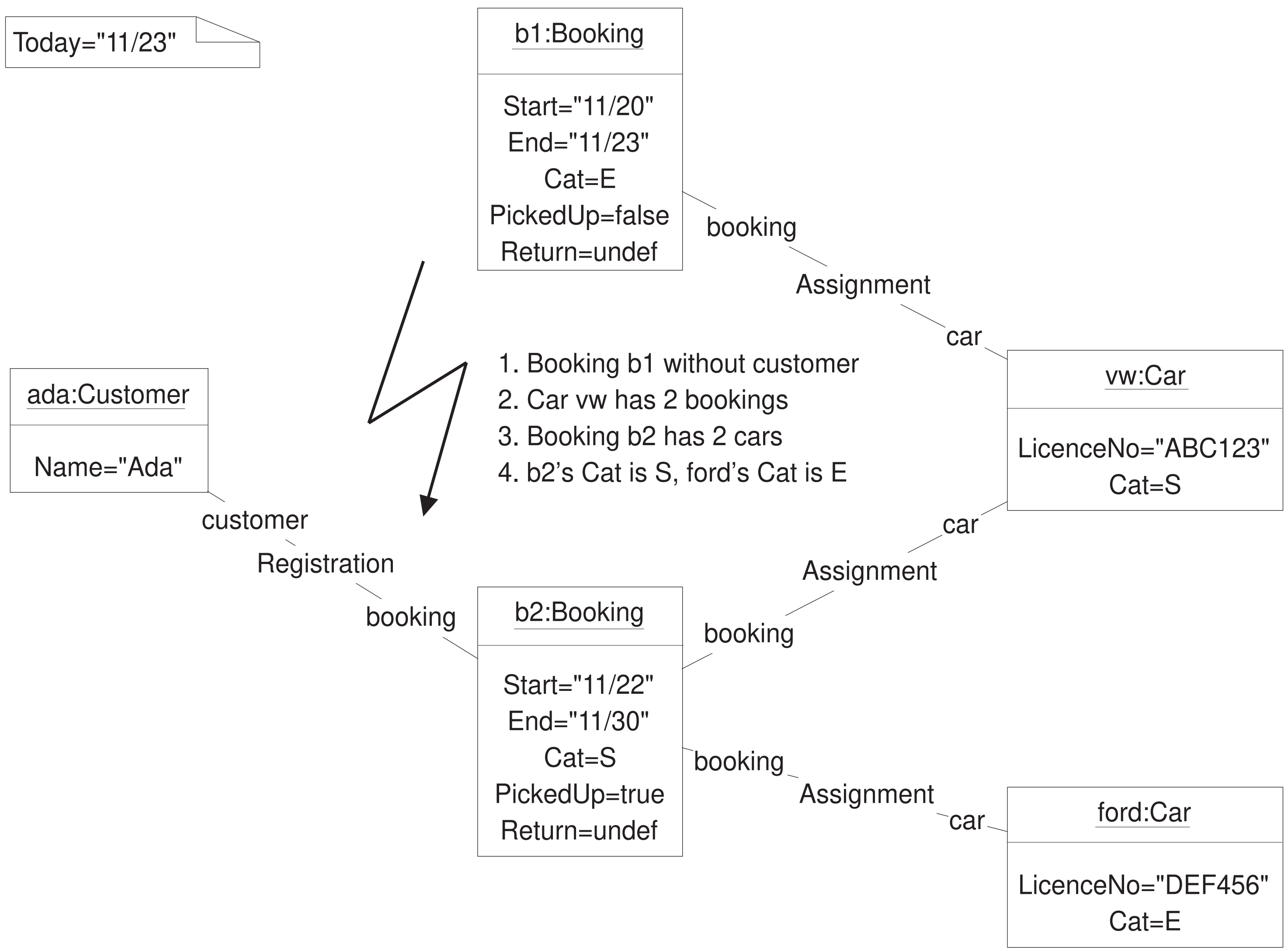
Allowed Object Diagram: 3 Classes, 3 Objects



Allowed Object Diagram: 3 Classes, 6 Objects

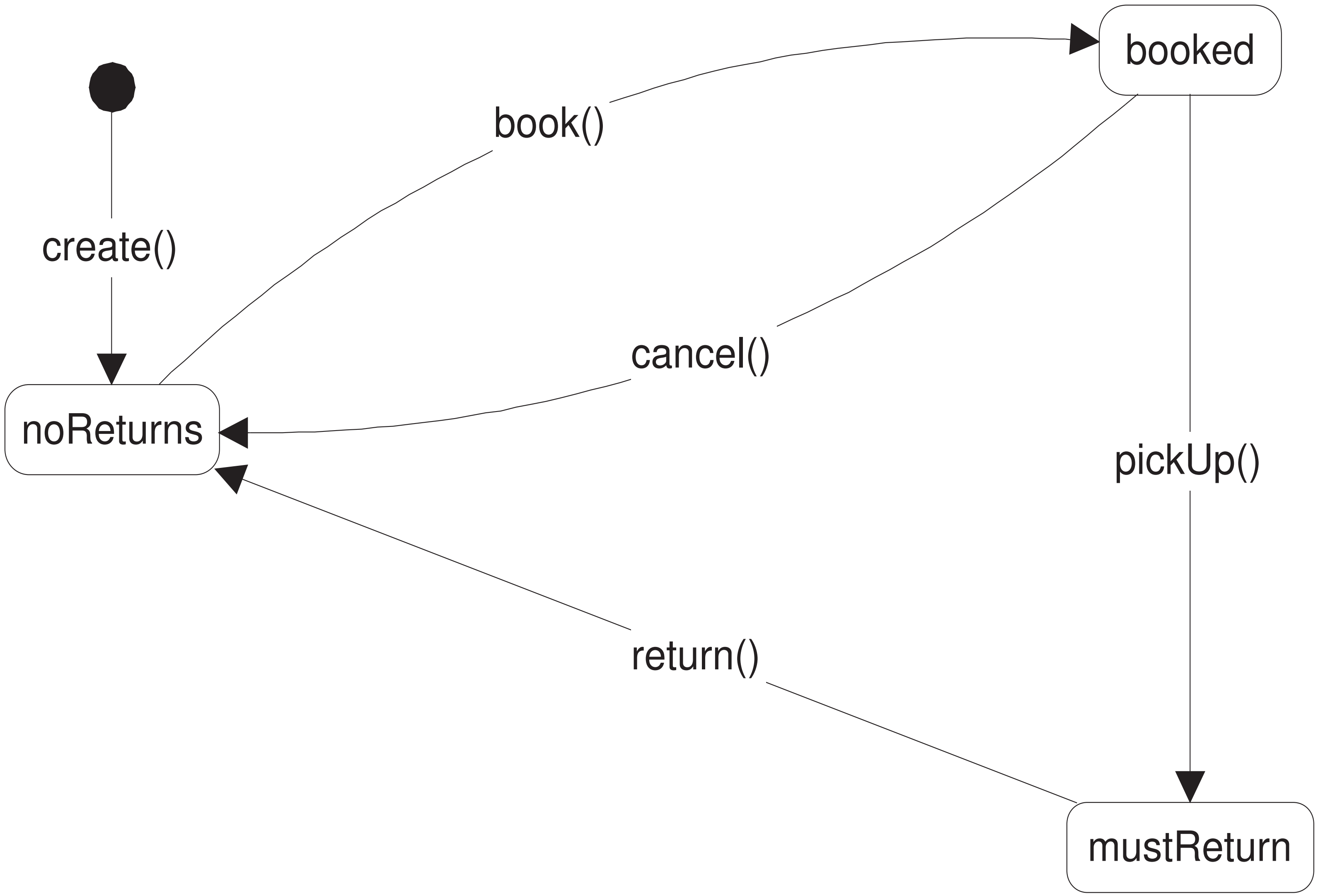


Disallowed Object Diagram

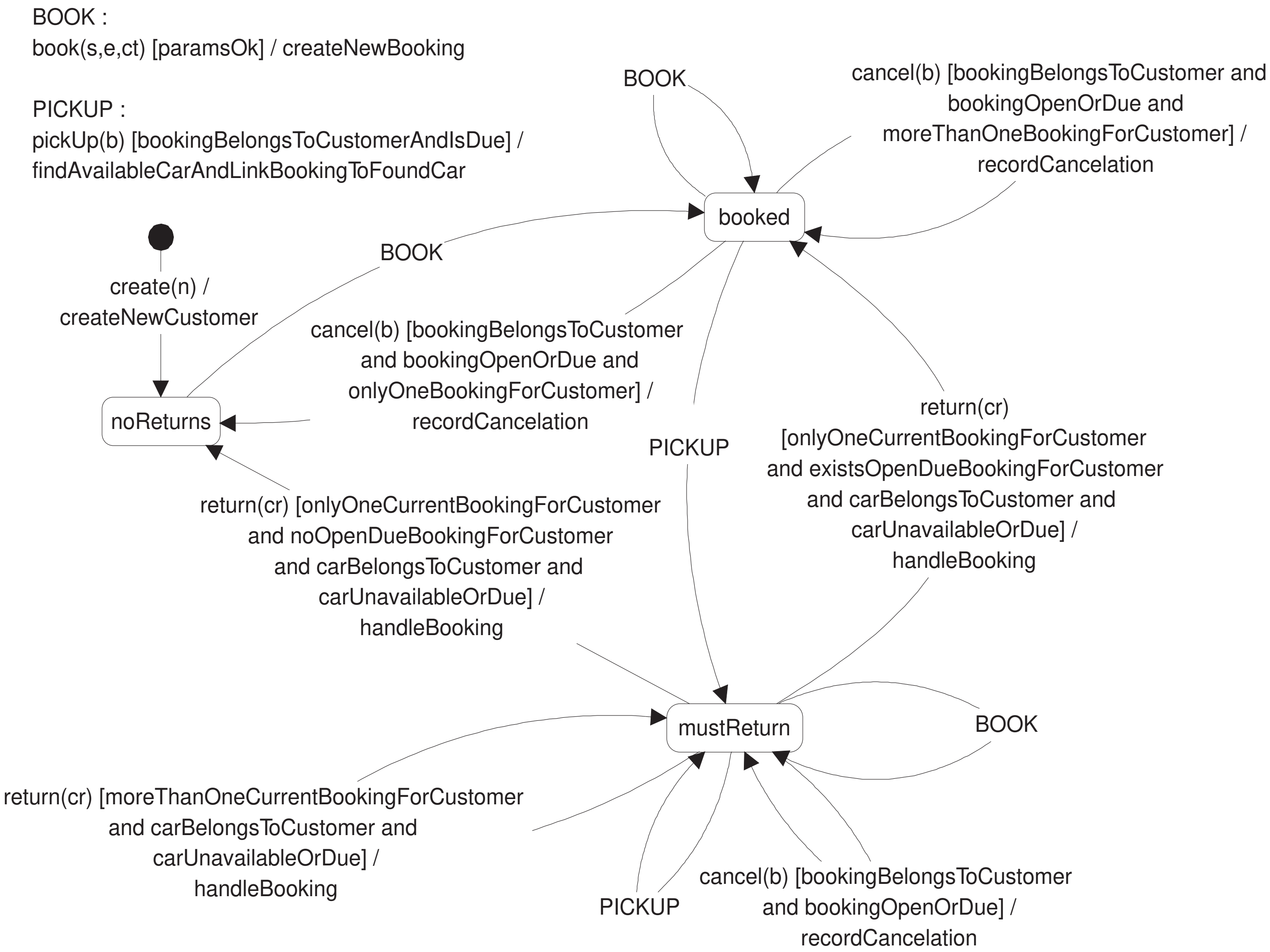


6.4 Statechart Diagrams

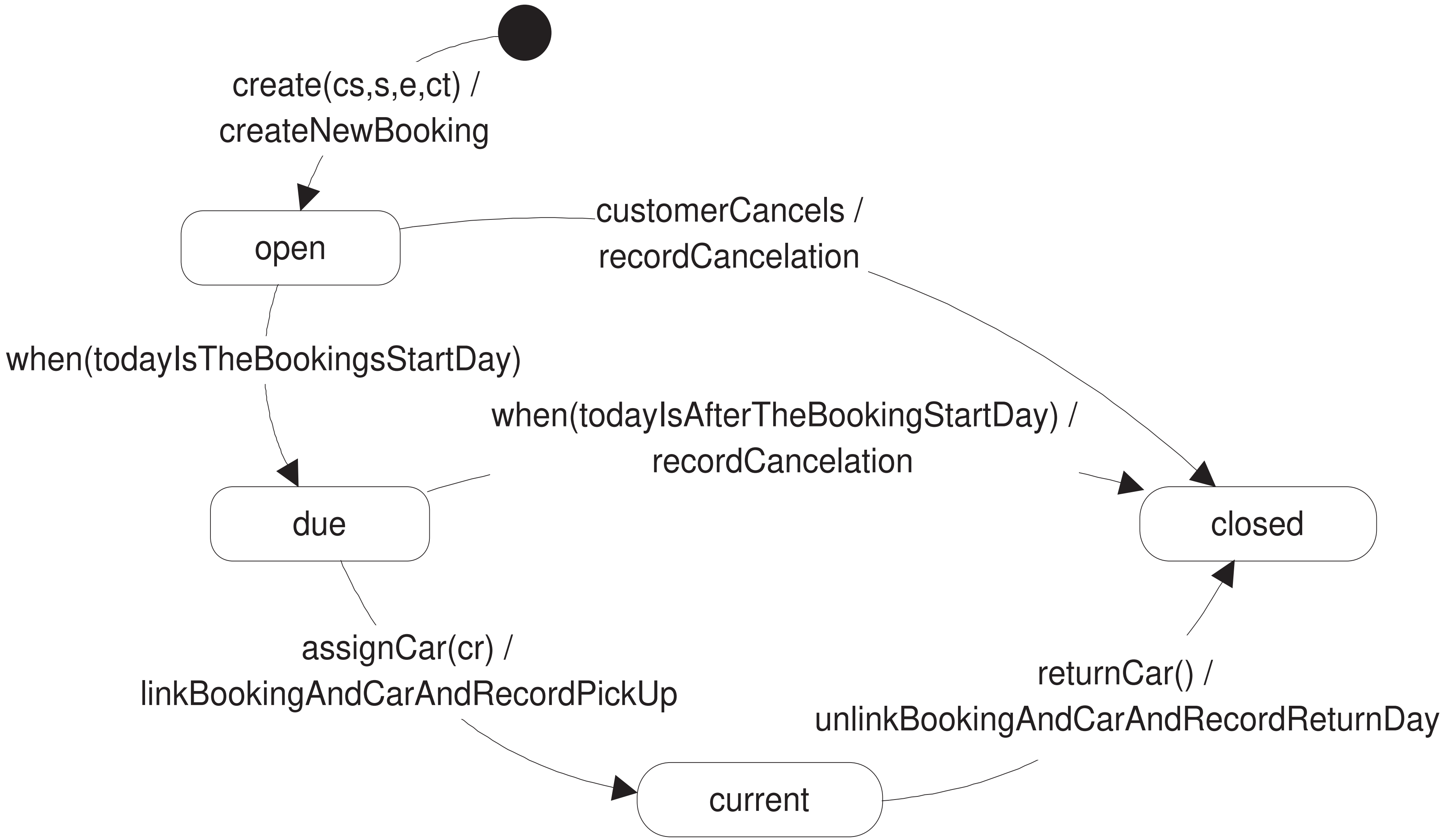
Main Idea of Customer Statechart



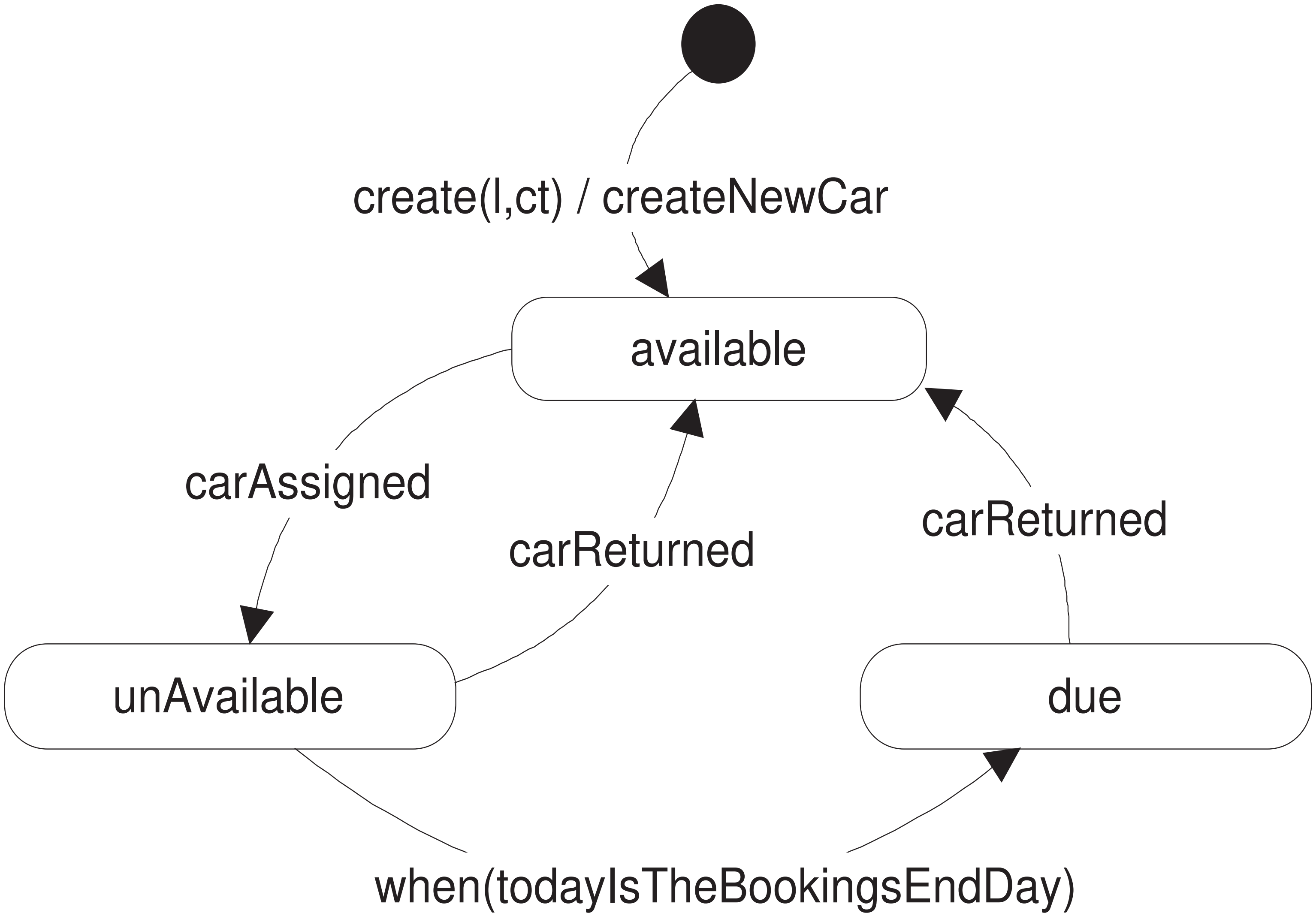
Customer Statechart with Textual Details



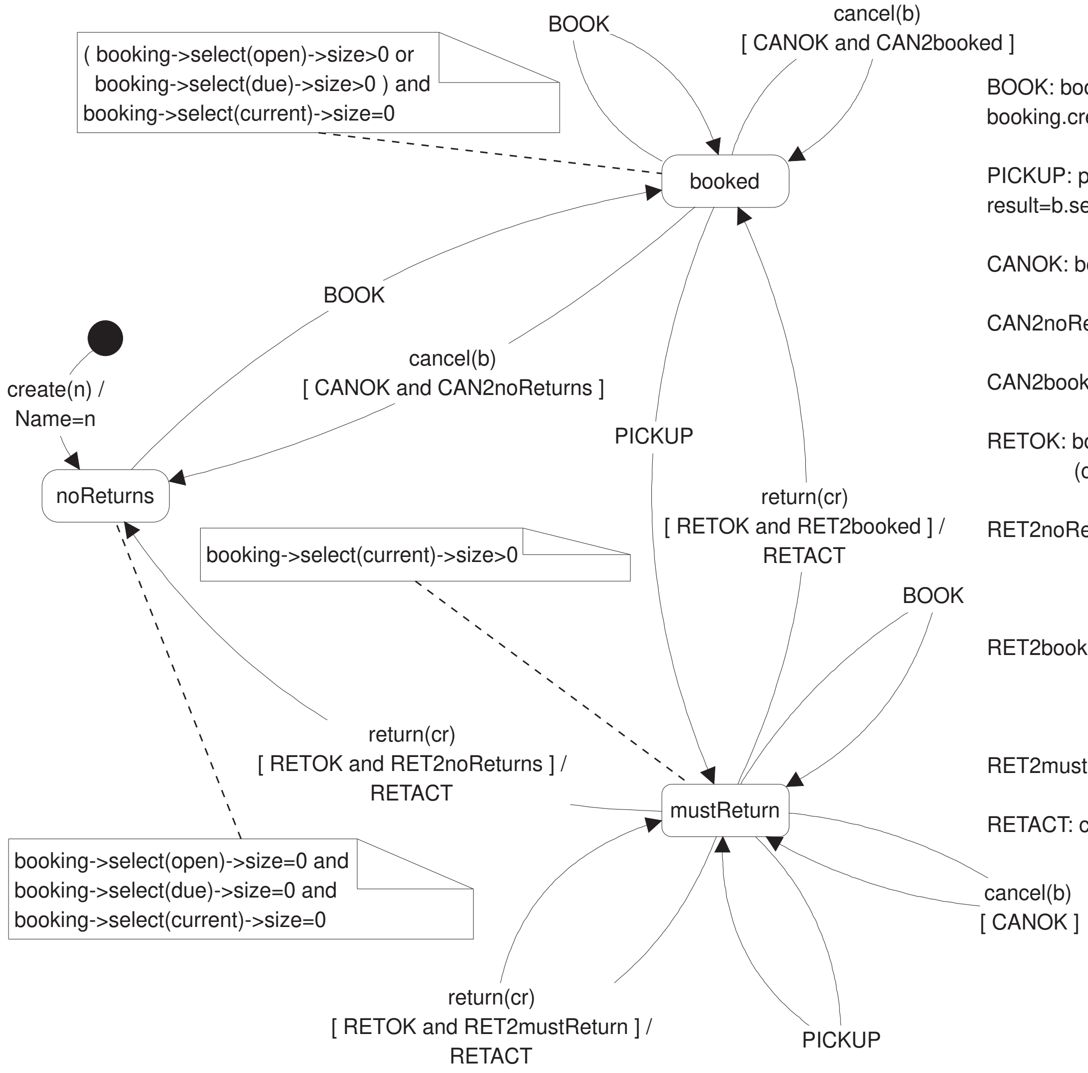
Booking Statechart with Textual Details



Car Statechart with Textual Details



Customer Statechart with Formal Details



BOOK: book(s,e,ct) [Today<=s and s<= e] /
booking.create(self,s,e,ct)

PICKUP: pickUp(b) [booking->includes(b) and b.due] /
result=b.searchAvailCar(); b.assignCar(result)

CANOK: booking->includes(b) and (b.open or b.due)

CAN2noReturns: booking->select(open or due)->size=1

CAN2booked: booking->select(open or due)->size>1

RETOK: booking.car->includes(cr) and
(cr.unAvailable or cr.due)

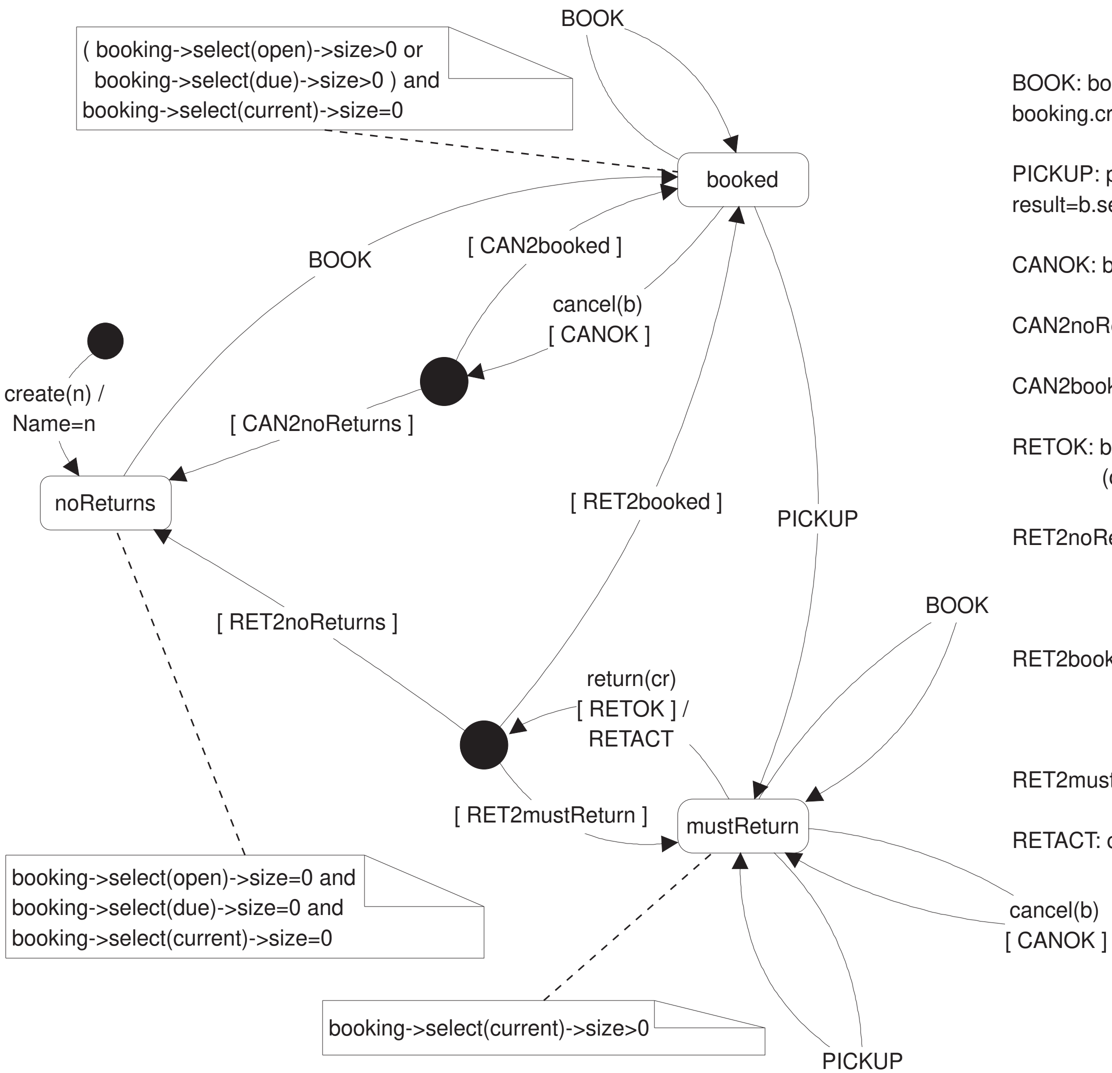
RET2noReturns: (booking->select(open)->size=0 and
booking->select(due)->size=0) and
booking->select(current)->size=1

RET2booked: (booking->select(open)->size>0 or
booking->select(due)->size>0) and
booking->select(current)->size=1

RET2mustReturn: booking->select(current)->size>1

RETACT: cr.booking.returnCar()

Customer Statechart with Formal Details Using Junction Points



BOOK: book(s,e,ct) [Today<=s and s<= e] /
booking.create(self,s,e,ct)

PICKUP: pickUp(b) [booking->includes(b) and b.due] /
result=b.searchAvailCar(); b.assignCar(result)

CANOK: booking->includes(b) and (b.open or b.due)

CAN2noReturns: booking->select(open or due)->size=1

CAN2booked: booking->select(open or due)->size>1

RETOK: booking.car->includes(cr) and
(cr.unAvailable or cr.due)

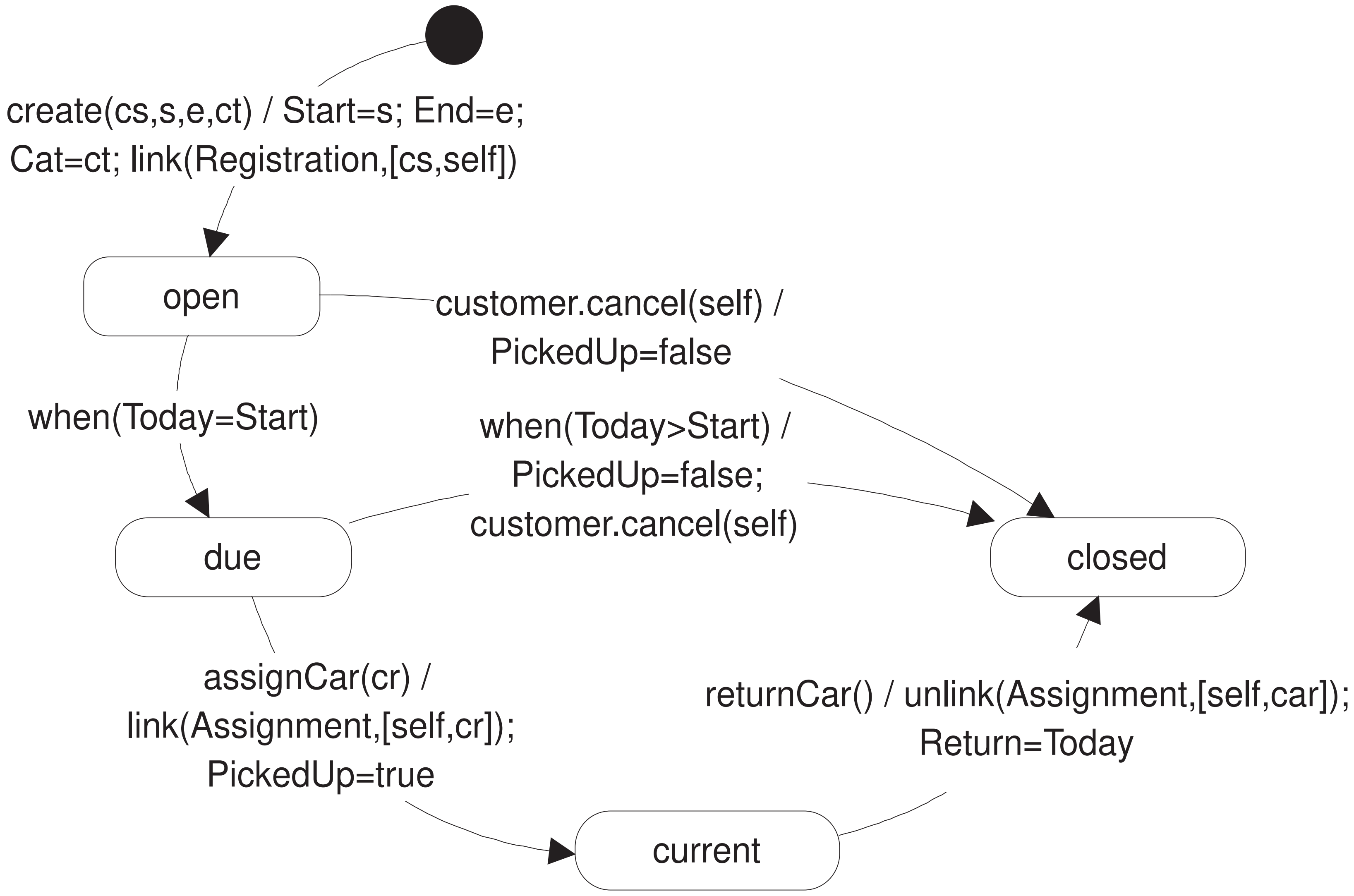
RET2noReturns: (booking->select(open)->size=0 and
booking->select(due)->size=0) and
booking->select(current)->size=1

RET2booked: (booking->select(open)->size>0 or
booking->select(due)->size>0) and
booking->select(current)->size=1

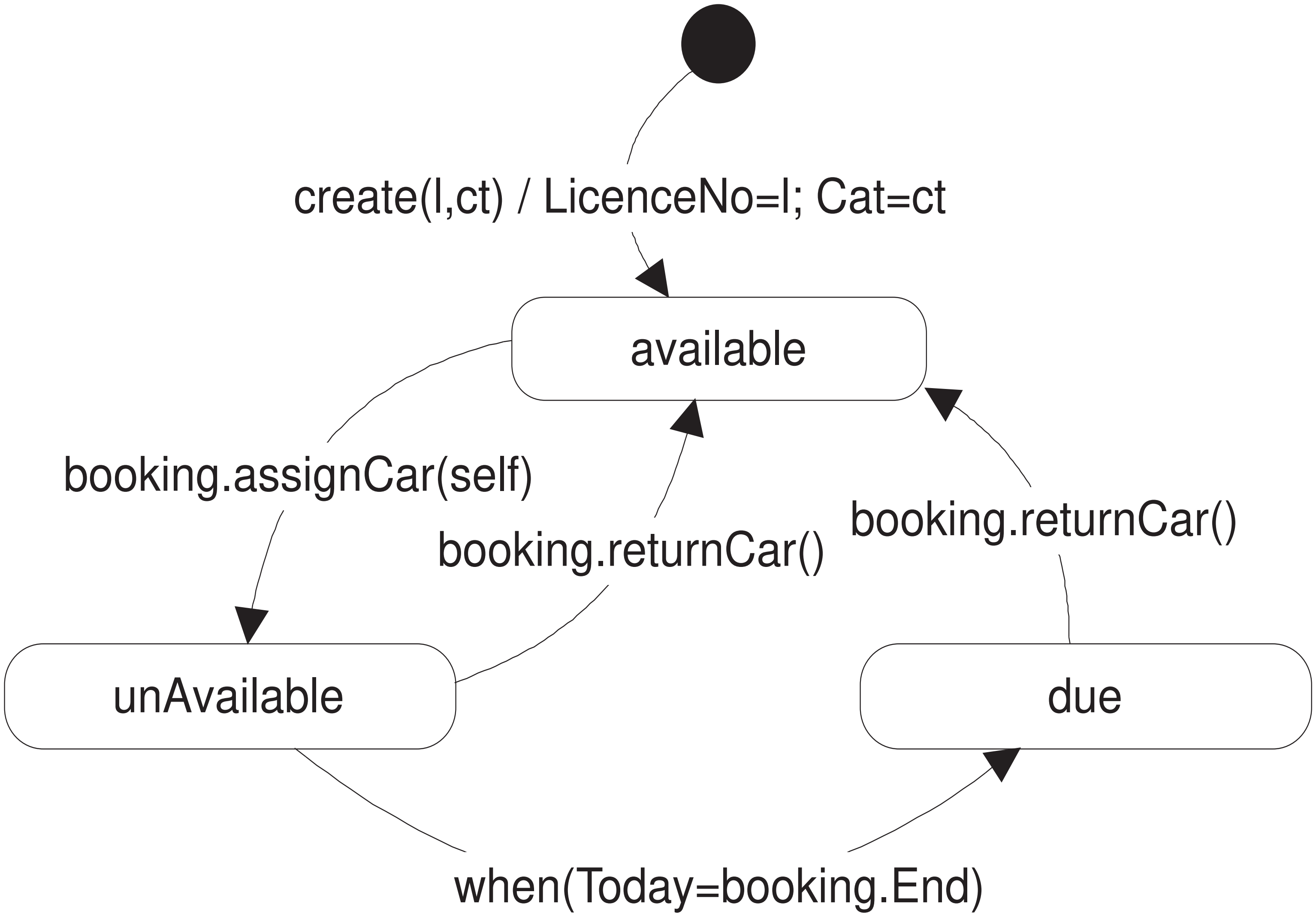
RET2mustReturn: booking->select(current)->size>1

RETACT: cr.booking.returnCar()

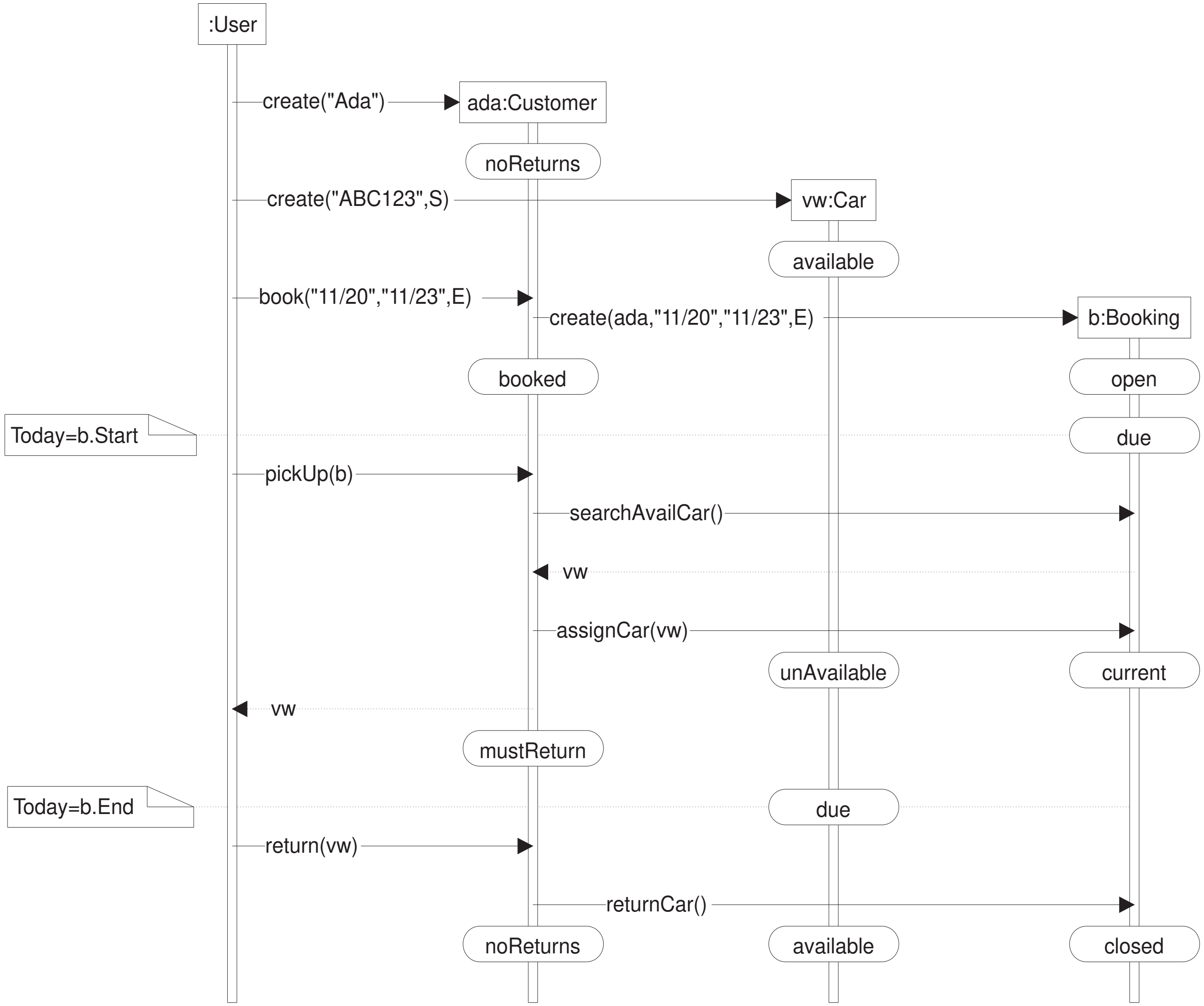
Booking Statechart With Formal Details



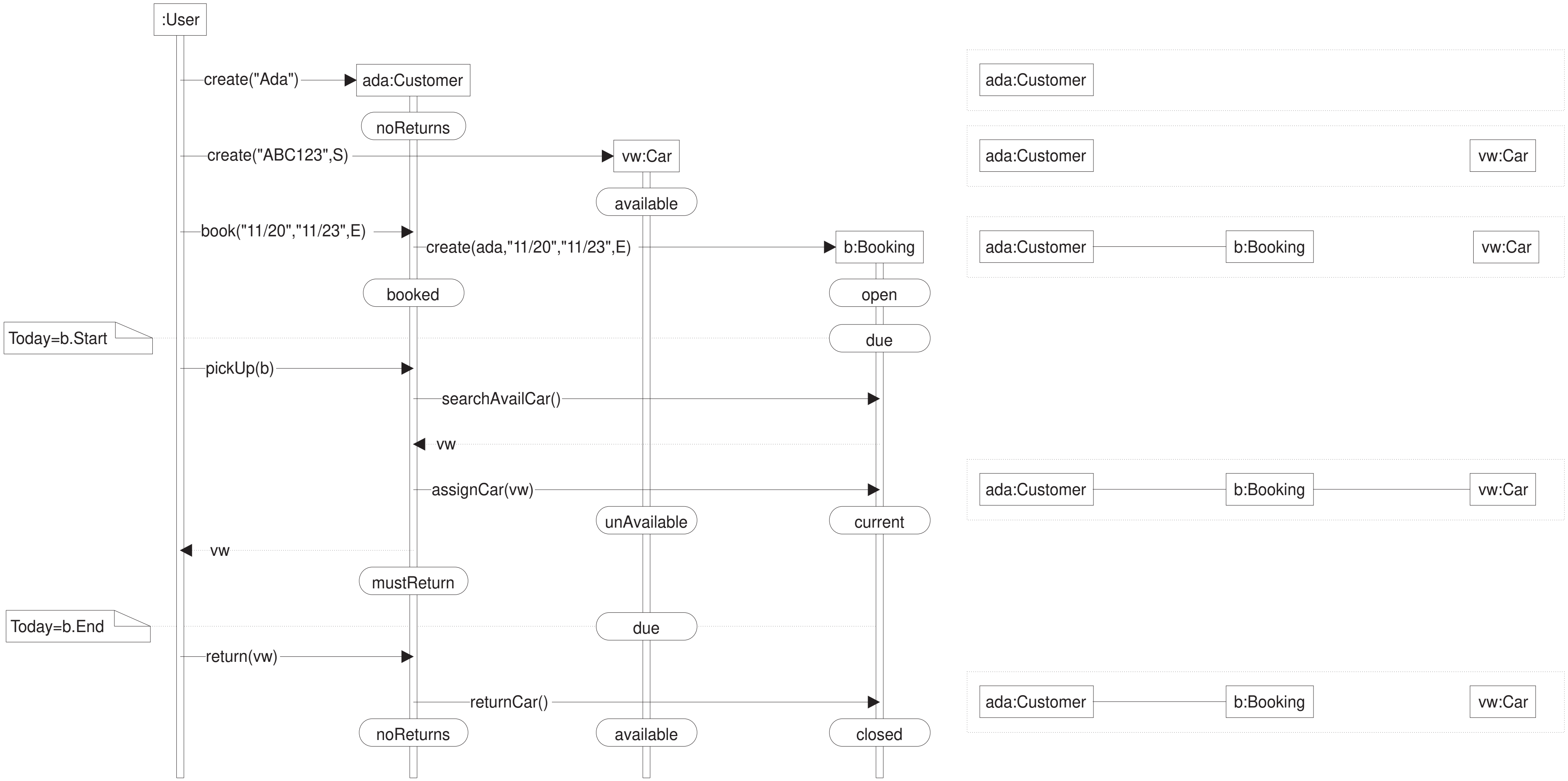
Car Statechart with Formal Details



Sequence Diagram for Booking: `Car.create; Booking.create`

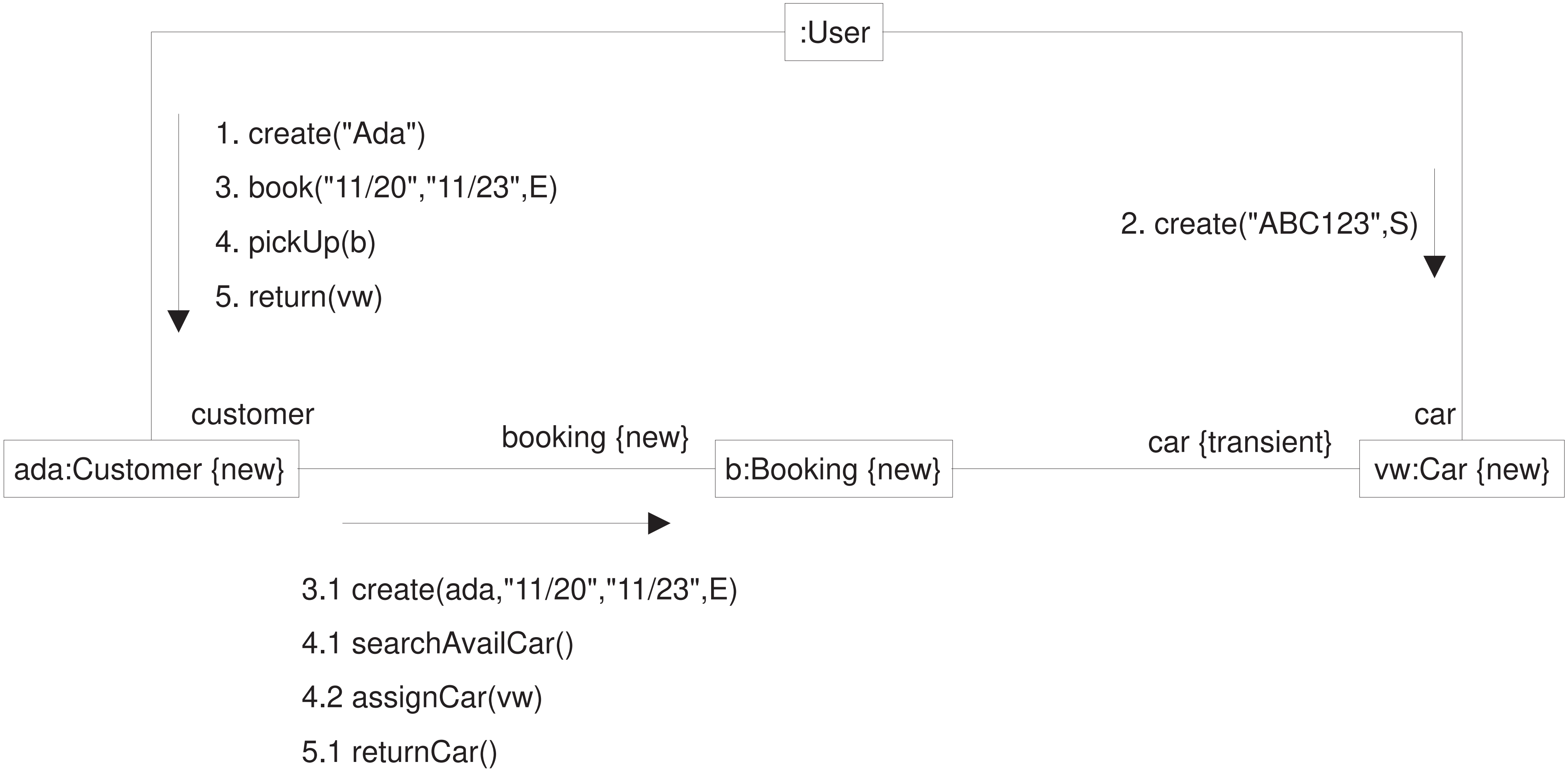


Sequence Diagram for Booking: `Car.create; Booking.create` (with objects)

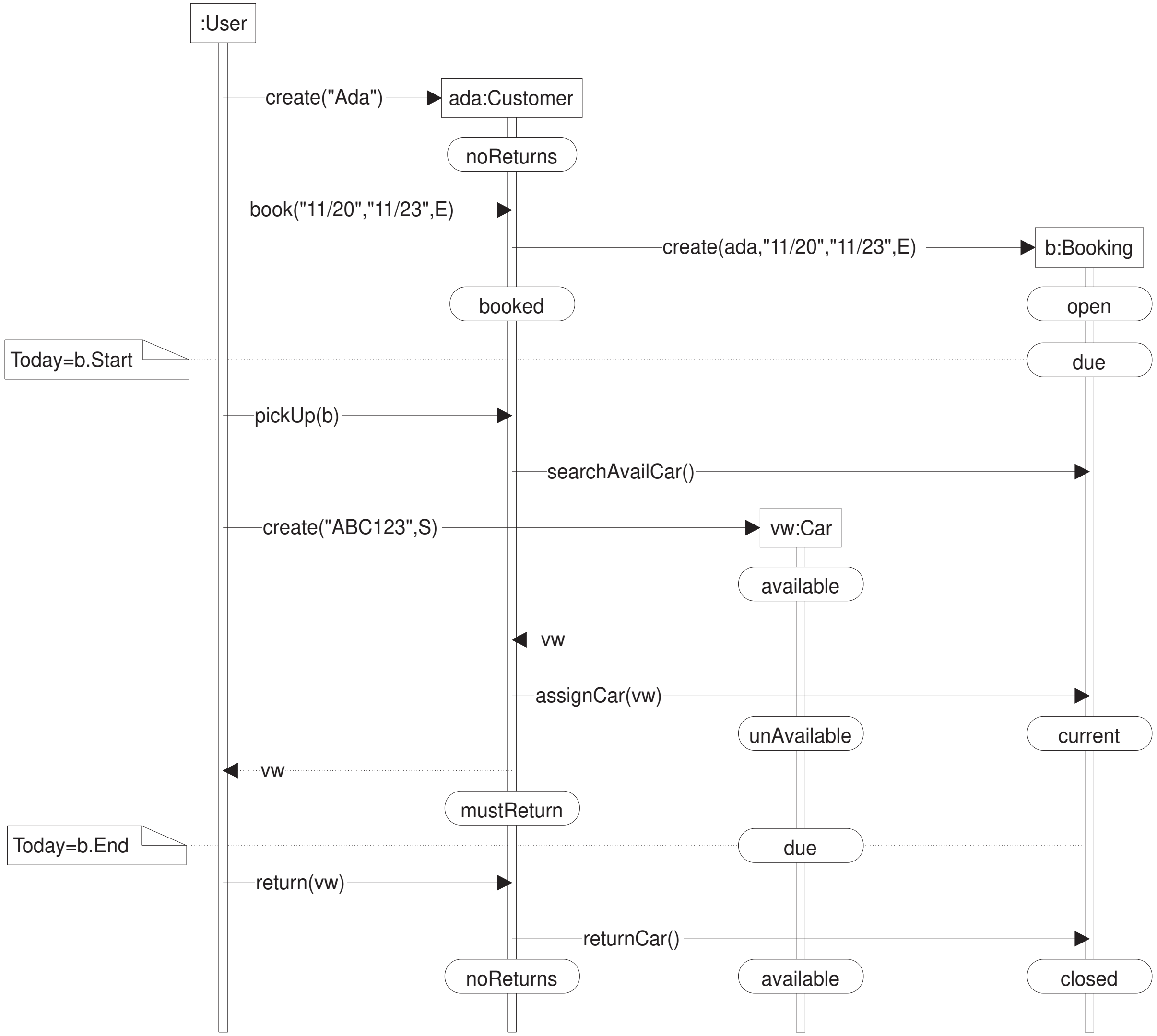


6.5 Collaboration Diagrams

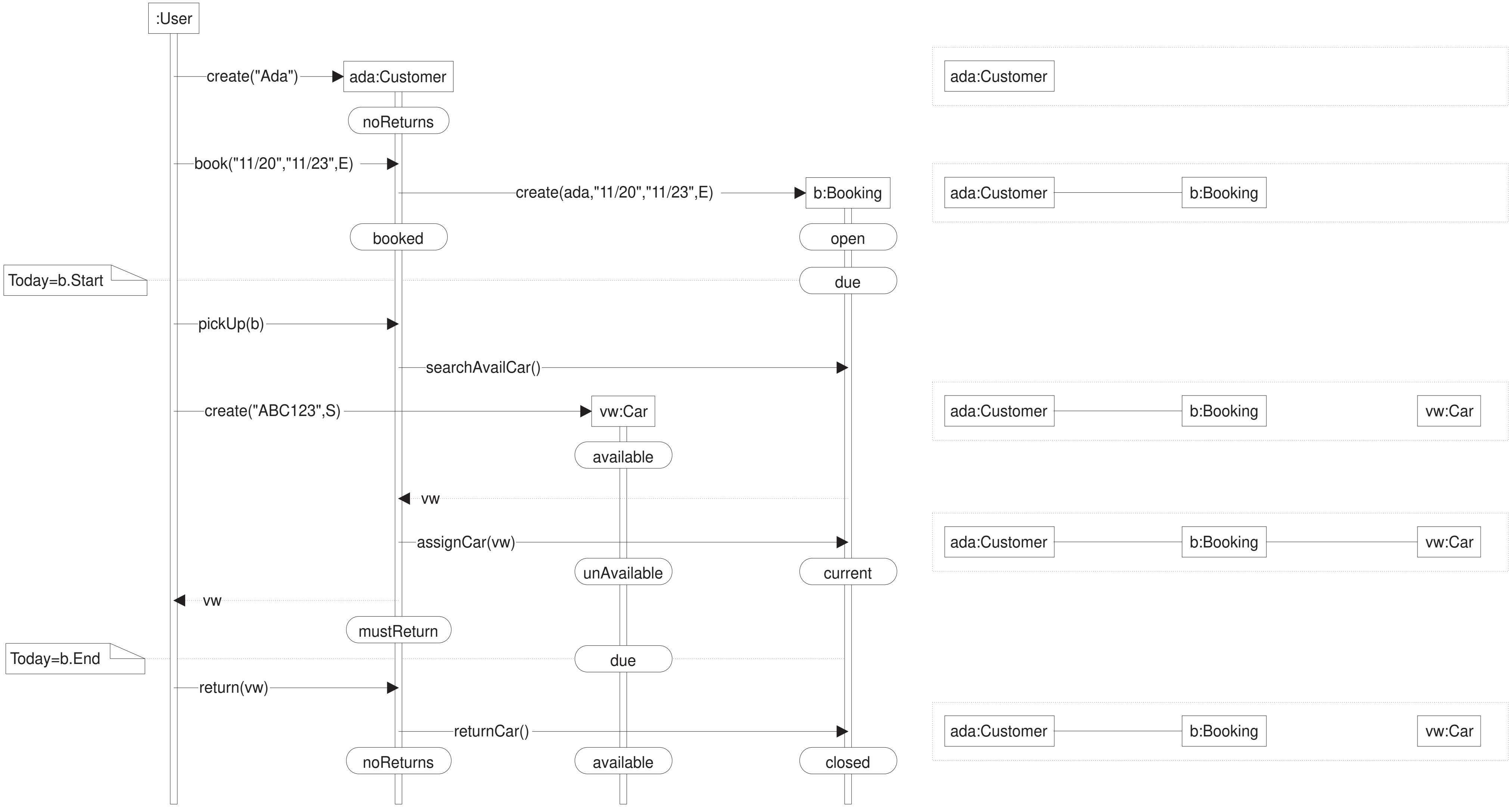
Collaboration Diagram for Booking: `Car.create; Booking.create`



Sequence Diagram for Booking: `Booking.create; Car.create`

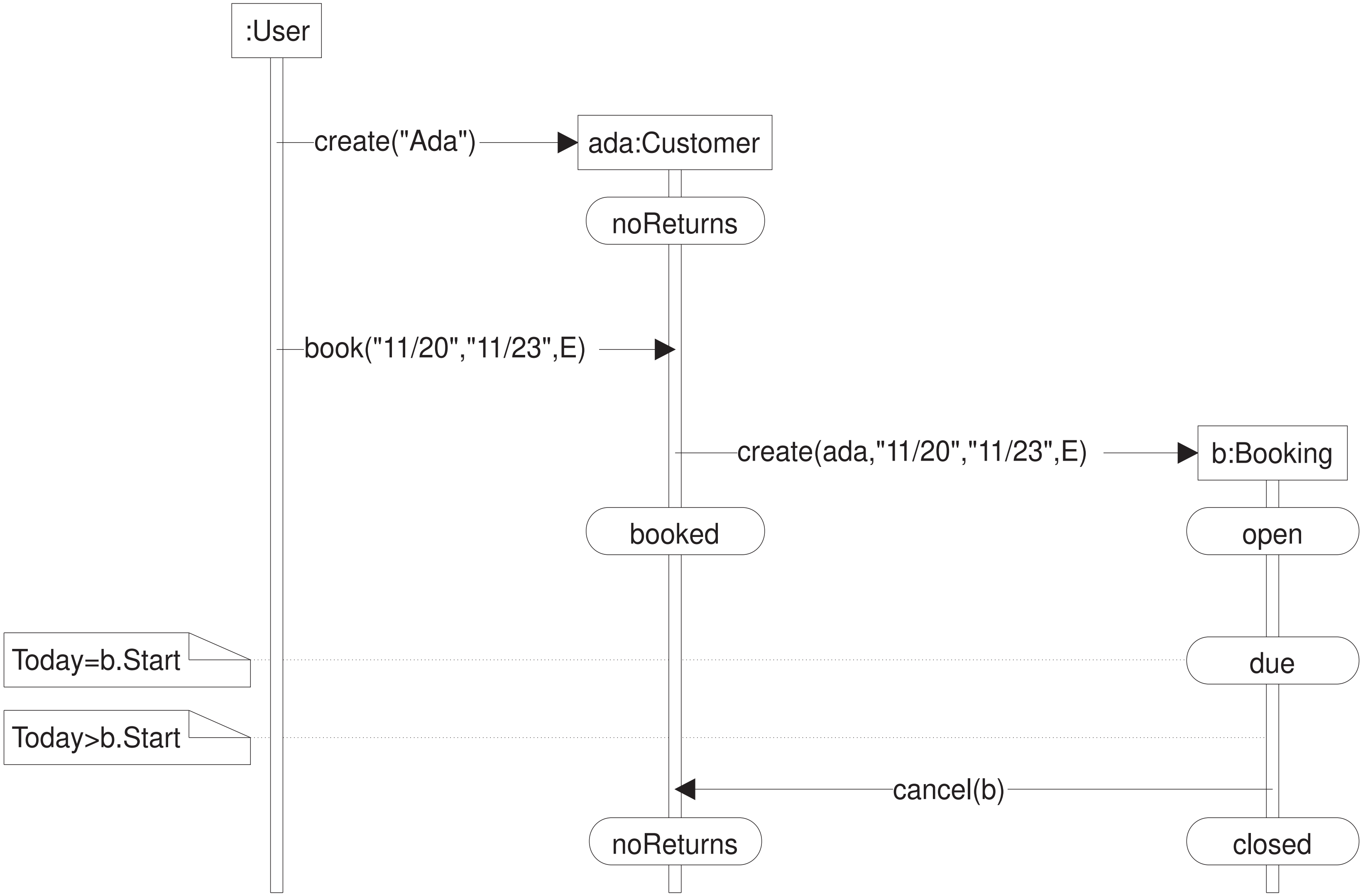


Sequence Diagram for Booking: `Booking.create; Car.create` (with objects)

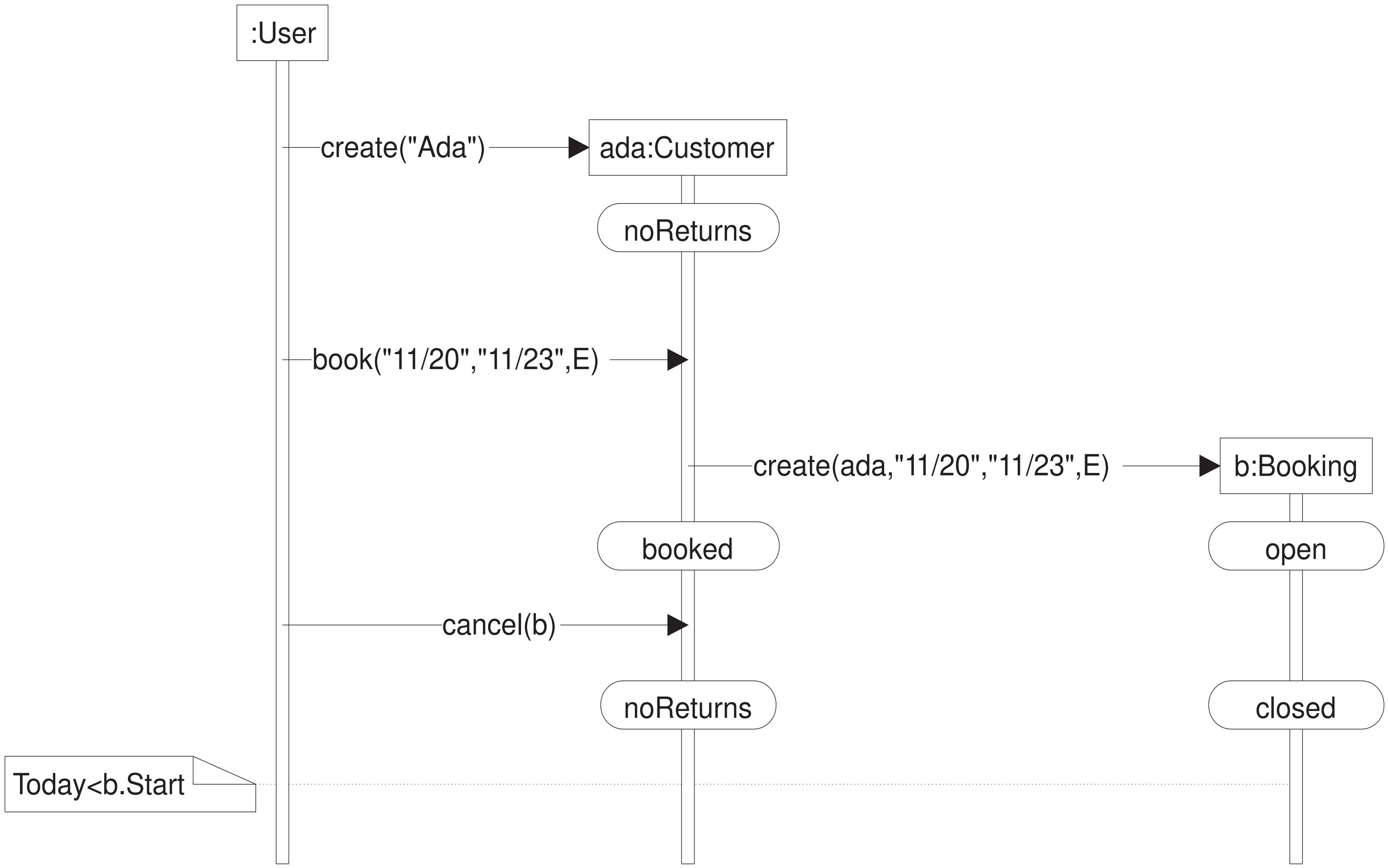


Collaboration Diagram for Booking: `Booking.create; Car.create`

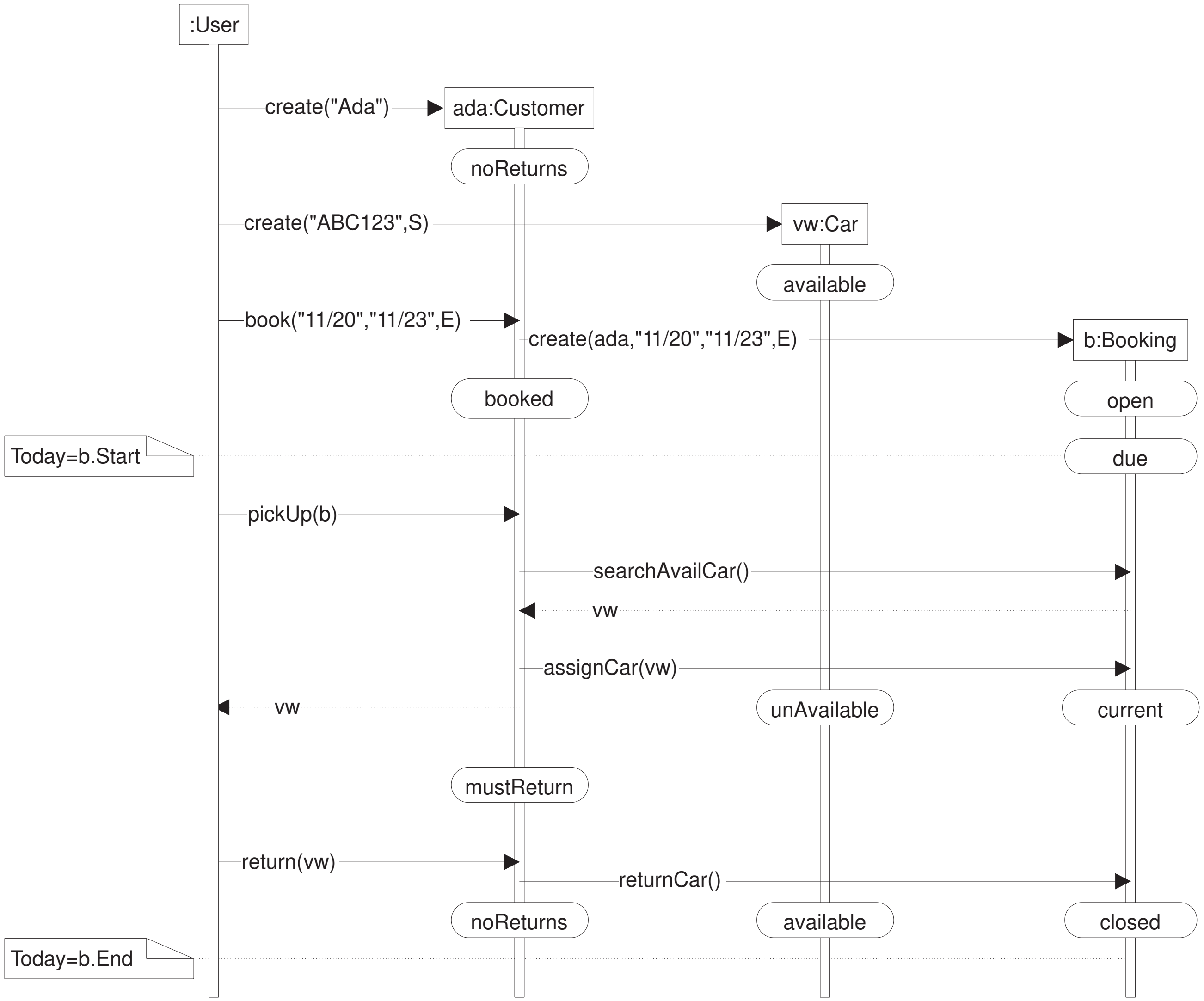
Sequence Diagram for Booking with Implicit Cancel



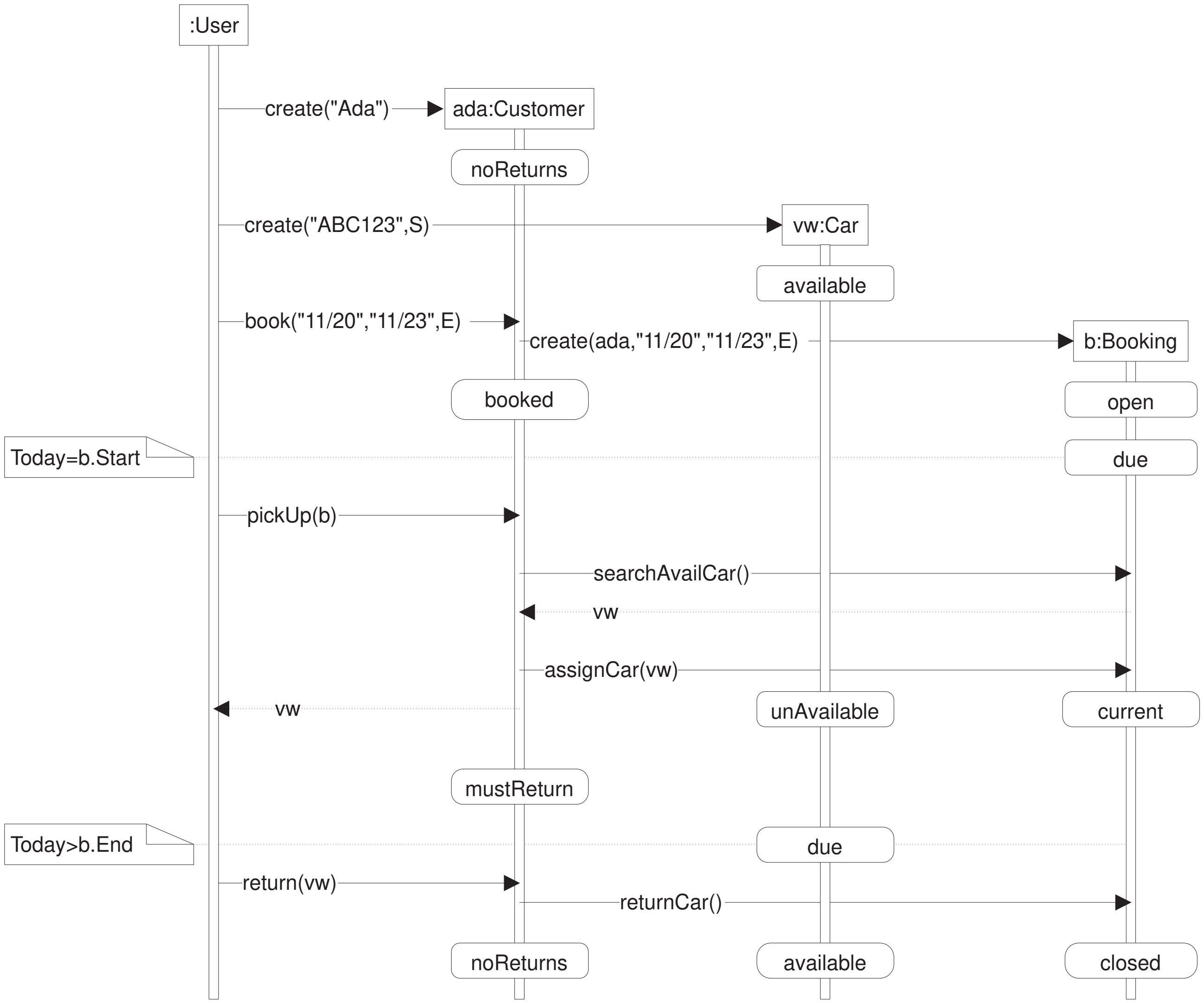
Sequence Diagram for Booking with Explicit Cancel



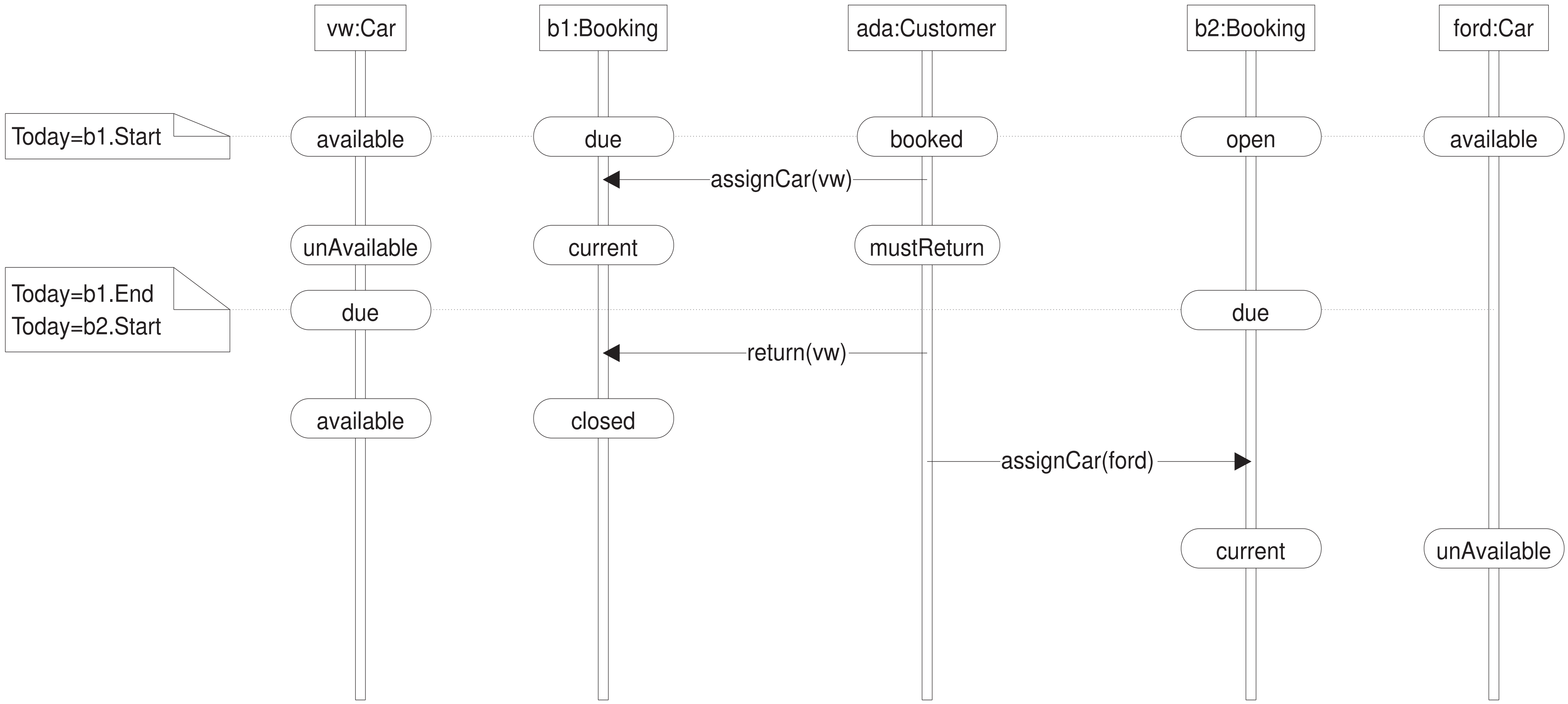
Sequence Diagram for Booking with Early Return



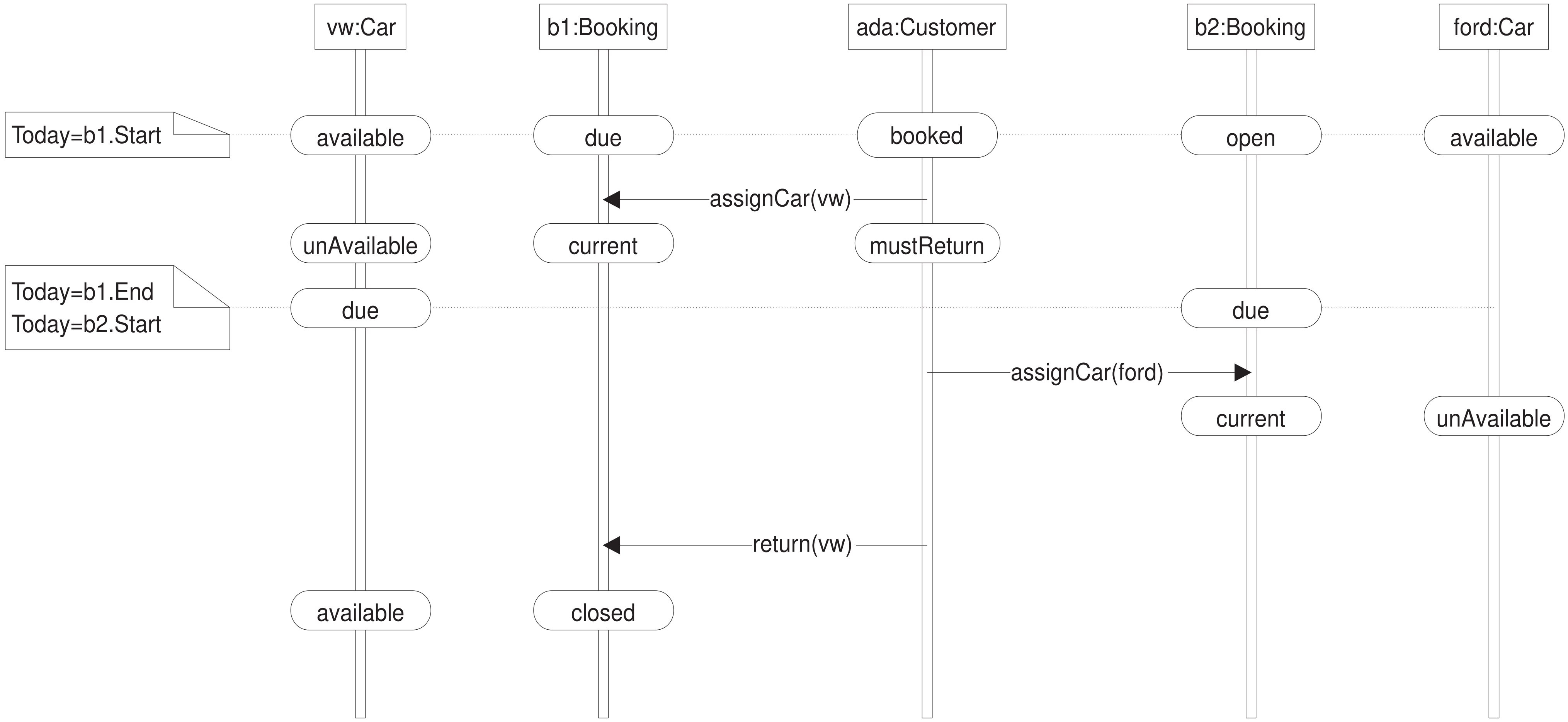
Sequence Diagram for Booking with Late Return



Sequence Diagram for Two Bookings: `b1.return; b2.assignCar`

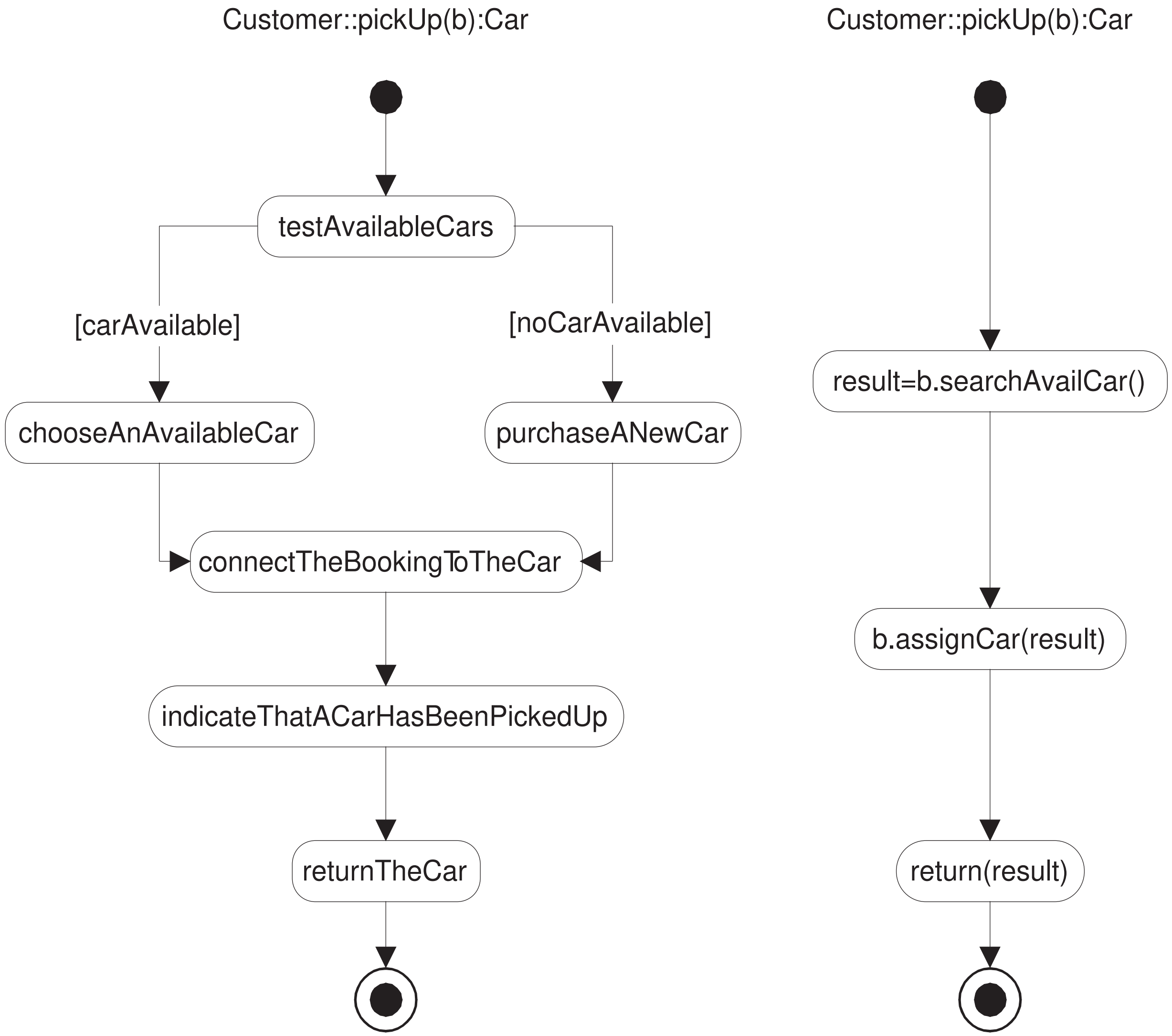


Sequence Diagram for Two Bookings: `b2.assignCar; b1.return`

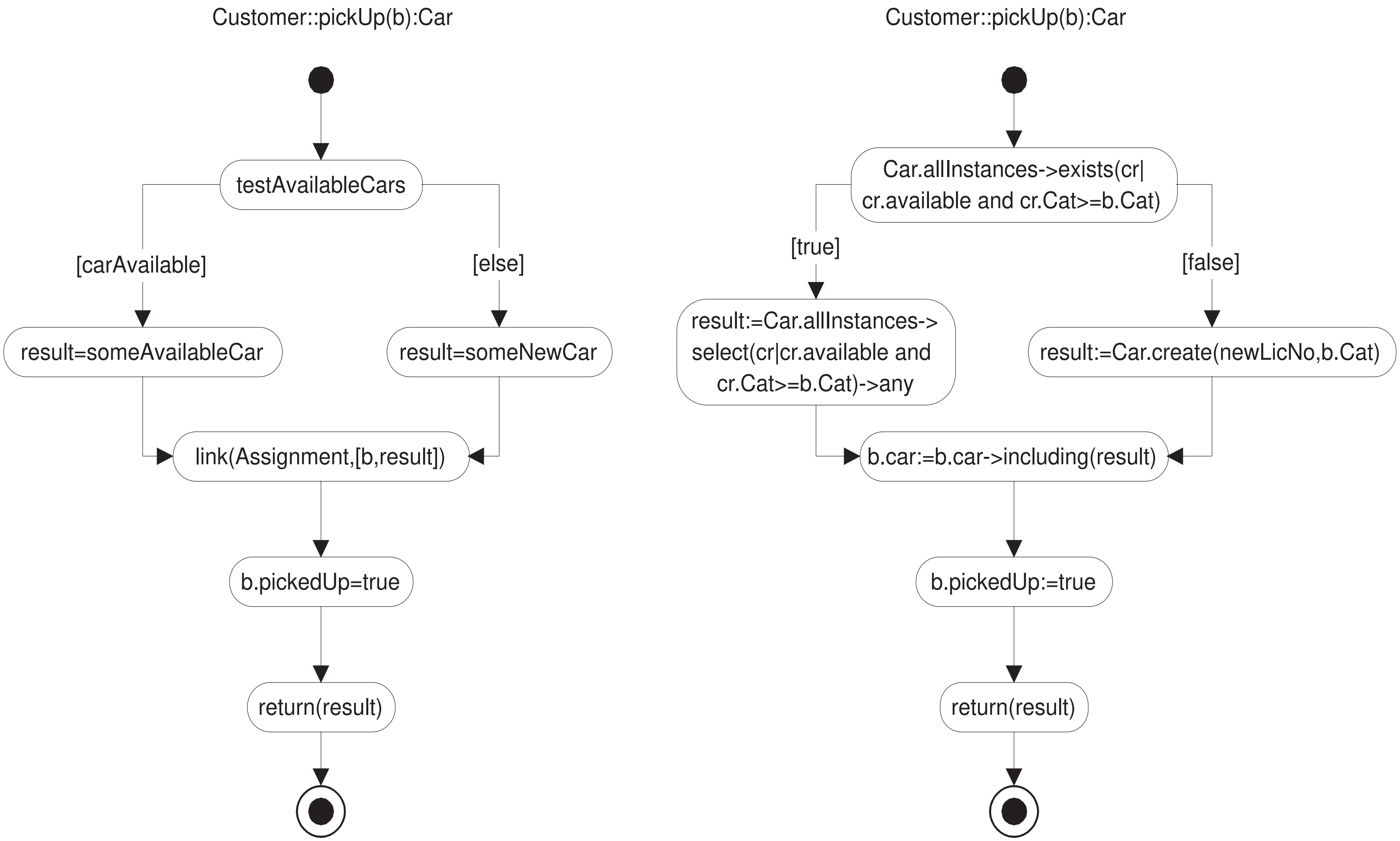


6.6 Closing

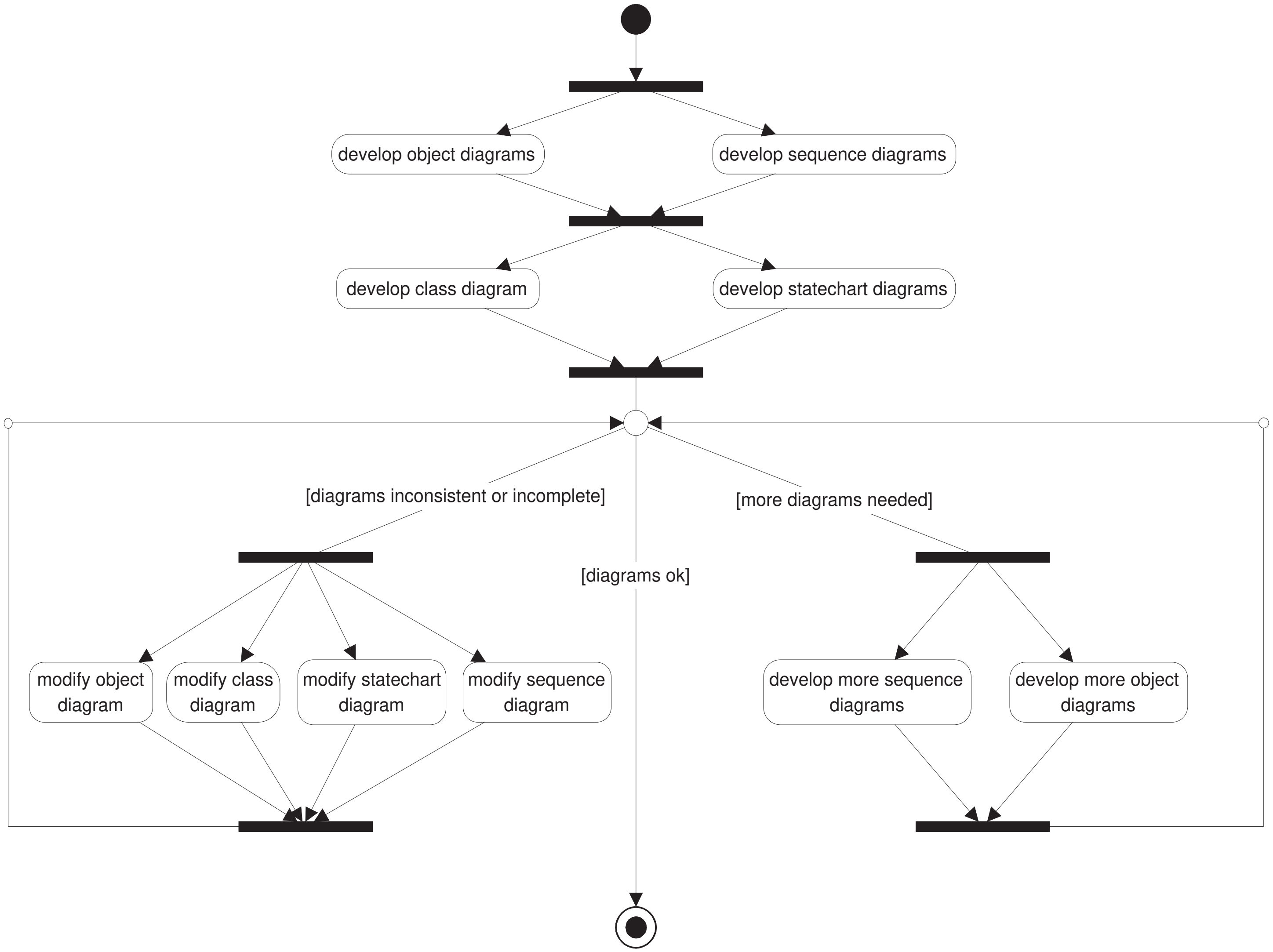
Activity Diagrams for `pickUp`: Textual Level and Operation Level



Activity Diagrams for `pickUp`: Statement Level and Formal Level



Developing a Consistent Model



Details for Diagram Consistency

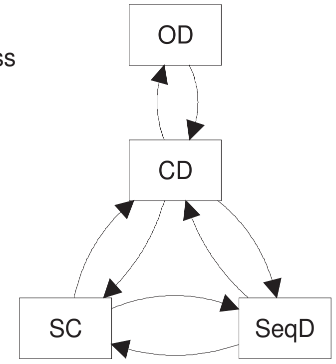
From class diagram to object diagrams
- for each class there is at least one object diagram with an object of that class
- for each attribute and role name there is at least one object diagram with an object with that attribute and role name

From class diagram to sequence diagrams
- for each class there is at least one sequence diagram with an object of that class
- for each operation there is at least one sequence diagram with that operation as a message

From class diagram to statechart diagrams
- for each attribute there is at least one operation that modifies that attribute in some statechart
- for each operation there is at least one statechart where that operation occurs as a call evant or as a call action

From statechart diagrams to class diagram
- each call event refers to an operation in a class
- each attribute and role name occurring in a guard refers to an attribute in a class and a role name of a class
- each call action, assignment action, and link/unlink action refers to an operation, attribute, and role name in a class

From object diagrams to class diagram
- each class of an object occurs as as class
- each attribute and role name refers to an attribute in a class and a role name of a class



From sequence diagram to class diagram
- each object refers to a class
- each message refers to an operation in a class

From sequence diagram to statechart diagram
- each state refers to a state in the statechart diagram
- each message sequence is allowed by at least one statechart event and action order
- each state sequence is allowed by at least one state sequence order

From statechart diagram to the sequence diagram
- each call action completely occurs in the sequence diagram (all sub-actions from the call action occur)