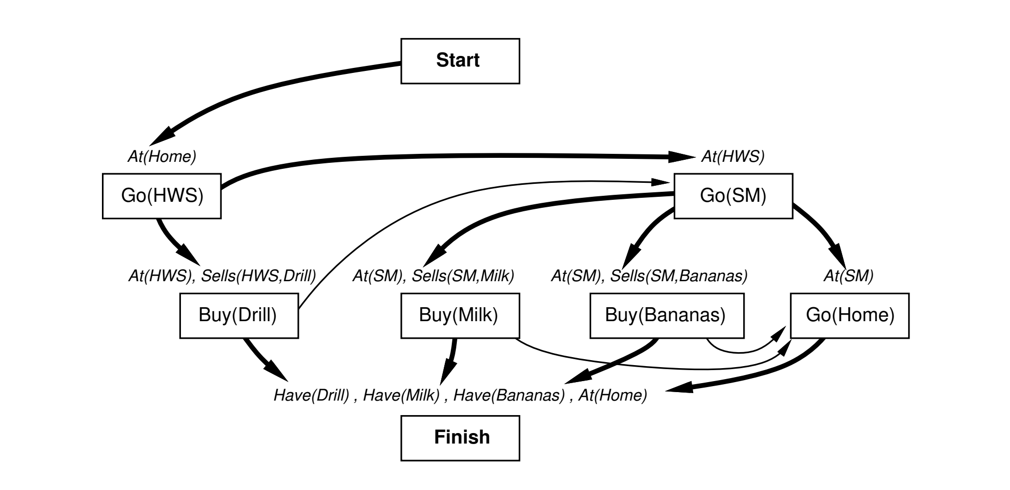

Figure 11.11 Causal link protection in the shopping plan. The $Go(HWS) \xrightarrow{At(HWS)} Buy(Drill)$ causal link is protected ordering the $Go(SM)$ step after $Buy(Drill)$, and the $Go(SM) \xrightarrow{At(SM)} Buy(Milk/Bananas)$ link is protected by ordering $Go(Home)$ after $Buy(Milk)$ and $Buy(Bananas)$.

Only the $At(Home)$ precondition of the *Finish* step remains unachieved. Adding a $Go(Home)$ step achieves it, but introduces an $At(x)$ precondition that needs to be achieved.[6] Again, the protection of causal links will help the planner decide how to do this:

- If it tries to achieve $At(x)$ by linking to $At(Home)$ in the initial state, there will be no way to resolve the threats caused by $Go(HWS)$ and $Go(SM)$.
- If it tries to link $At(x)$ to the $Go(HWS)$ step, there will be no way to resolve the threat posed by the $Go(SM)$ step, which is already constrained to come after $Go(HWS)$.
- A link from $Go(SM)$ to $At(x)$ means that x is bound to SM, so that now the $Go(Home)$ step deletes the $At(SM)$ condition. This results in threats to the $At(SM)$ preconditions of $Buy(Milk)$ and $Buy(Bananas)$, but these can be resolved by ordering $Go(Home)$ to come after these steps (Figure 11.11).

Figure 11.12 shows the complete solution plan, with the steps redrawn to reflect the ordering constraints on them. The result is an almost totally ordered plan; the only ambiguity is that $Buy(Milk)$ and $Buy(Bananas)$ can come in either order.

Let us take stock of what our partial-order planner has accomplished. It can take a problem that would require many thousands of search states for a problem-solving approach, and solve it with only a few search states. Moreover, the least commitment nature of the planner means it only needs to search at all in places where subplans interact with each other. Finally, the causal links allow the planner to recognize when to abandon a doomed plan without wasting a lot of time expanding irrelevant parts of the plan.

[6] Notice that the $Go(Home)$ step also has the effect $\neg At(x)$, meaning that the step will delete an *At* condition for some location yet to be decided. This is a **possible threat** to protected conditions in the plan such as $At(SM)$, but we will not worry about it for now. Possible threats are dealt with in Section 11.7.