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Dynaski, an Agent-based Model to Simulate Skiers in a Ski area

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Abstract

During winter holidays, most ski resorts expect a lot of skiers, who then congest the ski lifts in the corresponding ski areas. This article presents the first full multi-agent model of skiers in a ski area. Our purpose is to offer a decision-making tool for the operator and design engineering. Supply is represented in a graph of the ski area with slopes and ski lifts. Demand is addressed in a disaggregated way based on users' skiing abilities and the number of skiers per group. Each group moves around autonomously within the network. Three sub-models structure the agents' behavior. The choice model defines the itinerary of each agent, the queue model manages ski-lift congestion and the return journey model assists users in returning to their original point before the closing time of the ski lifts. A software has been implemented and a case study on a large ski area, La Plagne, has been performed to illustrate the effect of the replacement of a chair lift on the whole ski area.

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Keywords: Agent-based simulation, ski area, skier behavior, ski resort, mountain tourism, discrete choice

1. Introduction

In 2014, France is the first ski area in terms of surface and the number of ski lifts, and also the second most popular country after the United States in terms of skier days[1]. With 120,000 indirect jobs and 2 billion euros in French exports[2], winter tourism is of critical importance to the mountainous regions of France.

However, the expansion of the French ski areas is now over. Global warming has put a stop to the development of low-altitude ski resorts; under 1,500 m, the number of consistent snow days is insufficient. The large ski areas in high altitudes were developed next to nature reserves like Val d'Isère and Chamonix in France. The rise of environmental awareness, together with the fact that mountains have become a less appealing destination for skiing, are two factors

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which have ended the expansion of ski areas. Despite the decrease in consistent snow levels, the number of skiing days has remained stable in Europe and in the United States[3]. According to King et al.[4], snow fall is the main criterion that can decrease the number of skiers per day. Therefore, if the ski area remains the same, congestion will increase and, as a result, skiers' experience will be less comfortable and less enjoyable, mostly because of the amount of queueing to get to the ski lifts. Several studies have looked into relevant strategies to continue to attract skiers. The size of the ski area and the lake of skiing connections between ski resorts best account for the failure of ski-lift companies[56]. Long-term projections predict a reduction in the ski area and opening days despite the increasing number of snow-making installations[7]. The ski area companies will have to improve the efficiency of their ski lifts and slope networks.
In 2012, 3,500 ski lifts were installed in France, among which 2,300 surface lifts. Over the past 10 years, the number of ski lifts has decreased as surface lifts are now being replaced by detachable chair lifts[8]. Investment in ski lifts accounts for 40% of the ski-resort budget and each new detachable chair lift costs millions of euros. However, the tools used to predict improvement, flow and financial profits in the planning studies are out of date. Professionals only rely on their intuition and experience to decide on the location and size of a new infrastructure (based on the author's interviews with operators and engineering consultants). The statement of an American ski resort regarding the environmental impact[9] confirms that interaction between supply and demand was not originally meant to devise planning scenarios. A theoretical study (which, technically, could be operational in practice), carried out at the Serre-Chevalier station[10] has tried to explain the evolution of the ski-area infrastructure based on a fractal approach.
Ski-area operators are now trying to improve the quality of skiers' experience with field tools. A number of experiments and tests have been conducted to limit waiting time. In Switzerland, skiers can pay an extra charge to cut through the queue. In some resorts, people who are on their own can wait in a separate queue to fill in a chair, or in large ski areas, skiers can be kept up to date on the less congested zones in the ski area. On the other hand, the replacement of an old ski lift by another one with higher capacity is a more efficient measure. However, a ski area is complex and if all ski lifts are optimized, skiers will spend less time in them and more time skiing on the ski slopes and waiting in the ski-lift queues. As an urban transportation network, the ski area is an integrated system and every single change in this infrastructure affects the ski area as a whole. Here is another idea: as the production of artificial snow makes up for the lack of natural snow, the minimization of the time spent waiting for the lifts can mainly be achieved with a new lift infrastructure. Unfortunately, technical tools for testing scenarios and producing sociological, environmental and economic indicators are still missing and, consequently, cannot help preliminary studies of the new infrastructures. Our purpose is to build a model that simulates the skiers' itineraries in the ski area, with and without the new infrastructure, and then makes it possible to compare the benefits afforded by each possible solution.

The transportation sector uses models to simulate and forecast the flow on routes and urban networks. All the new transportation projects are socio-economically justified by traffic modeling, and powerful software companies provide integrated tools for modeling and simulating impacts. The implemented models are often static and rarely dynamic. Agent-based models such as Matsim[11] are used in transportation to assign disaggregated flow in the urban network, but the temporal complexity of the model and lack of data force users to simplify models. Moreover, agent-based models focus on the limited point of view of the agent, unlike the overall vision of the economic models[12]. In addition, agent-based models are mainly used to simulate behaviors in an emergency, as is the case with evacuation models[13], user feedback on real-time information[14], or to simulate innovative transportation systems such as autonomous vehicles or carpooling[1516]. Walt Disney Company developed an agent-based model to plan and manage crowd flows in theme park environments[17] (Huerre). The group effect influences the crowd flow as well as the queues at the tourist attractions. These kinds of models are based on specific microscopic behaviors which minimize travel time to reach a specific destination. Compared to an urban network, the number of agents in a ski area is limited and the agents' behaviors are predictable in part.
Very few studies link the simulation approach to mobility in a ski area. A Swiss project, Juste-Neige[18], aims to predict snow thickness using an agent-based approach. The model is mainly based on turnslide counts. Skiers are generated according to the evolution of the ski-lift counts. The agents choose slopes that match the numbers validated by each count. A queue model[19] allows calculation of waiting time at the ski lifts, without taking account of any vacant seats due to the composition of the groups. An internship report[20] presents an optimization of the infrastructure. The methodology is based on the maximization of the theoretical capacity of the ski area and the speed of the lifts. Unfortunately, the model is very theoretical and the time complexity is exponential.