Problem A: Managing The Zambezi RiverThe Kariba Dam on the Zambezi River is one of the larger dams in Africa. Its  
construction was controversial, and a 2015 report by the Institute of Risk Management  
of South Africa included a warning that the dam is in dire need of maintenance. A number of options are available to the Zambezi River Authority (ZRA) that might  
address the situation. Three options in particular are of interest to ZRA:  
(Option 1) Repairing the existing Kariba Dam,  
(Option 2) Rebuilding the existing Kariba Dam, or  
(Option 3) Removing the Kariba Dam and replacing it with a series of ten to  
twenty smaller dams along the Zambezi River.  
There are two main requirements for this problem:  
Requirement 1 ZRA management requires a brief assessment of the three  
options listed, with sufficient detail to provide an overview of potential costs and  
benefits associated with each option. This requirement should not exceed two  
pages in length, and must be provided in addition to your main report.  
Requirement 2 Provide a detailed analysis of Option (3) - removing the Kariba  
Dam and replacing it with a series of ten to twenty smaller dams along the  
Zambezi river. This new system of dams should have the same overall water  
management capabilities as the existing Kariba Dam while providing the same or  
greater levels of protection and water management options for Lake Kariba that  
are in place with the existing dam. Your analysis must support a recommendation  
as to the number and placement of the new dams along the Zambezi River.  
In your report for Requirement 2, you should include a strategy for modulating the water  
flow through your new multiple dam system that provides a reasonable balance  
between safety and costs. In addition to addressing known or predicted normal water  
cycles, your strategy should provide guidance to the ZRA managers that explains and  
justifies the actions that should be taken to properly handle emergency water flow  
situations (i.e. flooding and/or prolonged low water conditions). Your strategy should  
provide specific guidance for extreme water flows ranging from maximum expected  
discharges to minimum expected discharges. Finally, your recommended strategy  
should include information addressing any restrictions regarding the locations and  
lengths of time that different areas of the Zambezi River should be exposed to the most  
detrimental effects of the extreme conditions.  
Your MCM submission should consist of three elements: a standard 1 page MCMSummary Sheet, a 1-2 page brief assessment report (Requirement 1), and your mainMCM solution (Requirement 2) not to exceed 20 pages for a maximum submission of23 pages. Note: Any appendices or reference pages you include will not count towardsthe 23 page limit

问题A:问题A：管理赞比西河

赞比西河上的卡里巴水坝是非洲较大的水坝之一。它的建筑是有争议的，以及风险管理研究所的2015年报告的南非包括一个警告，大坝是急需维修。一个  
赞比西河管理局（ZRA）可能有多种选择解决的情况。 ZRA特别感兴趣的有三个选项：  
（选项1）修复现有的Kariba水坝，  
（选项2）重建现有的卡里巴大坝，或  
（选项3）拆下Kariba水坝，并用十个系列替换沿赞比西河的二十个较小的水坝。  
这个问题有两个主要要求：要求1 ZRA管理需要对三者进行简要评估选项，并提供足够的详细信息以提供潜在成本的概述每个选项相关的好处。This requirement should not exceed two pages in length, and must be provided in addition to your main report.

要求2详细分析选项（3） - 去掉（删除or毁掉）Kariba水坝，并用一系列十到二十个较小的水坝替换它赞比西河。这个新的水坝系统应该具有相同的总水量管理能力作为现有的Kariba水坝，同时提供相同或更高水平的保护和水管理选项卡拉比湖与现有的水坝。您的分析必须支持建议关于沿赞比西河的新水坝的数量和位置。 在您的要求2报告中，您应该包括一个调节水的策略

流经你的新多重坝系统，提供一个合理的平衡安全和成本之间。除了解决已知或预测的正常水周期，您的策略应为ZRA经理提供指导，解释和证明应该采取的行动以正确处理应急水流情况（即洪水和/或延长的低水况）。你的策略应该

为极端水流量从最大预期水平提供具体指导放电至最小预期放电。最后，你的推荐策略应包括解决有关地点的任何限制的信息赞比西河不同地区应该暴露在最多的时间长度有害的极端条件的影响。您的MCM提交应包含三个要素：标准的1页MCM摘要表，1-2页简要评估报告（要求1）和您的主要MCM解决方案（要求2）不超过20页，最大提交量为23页。注意：您添加的任何附录或参考页都不会计入23页的限制

Problem B: Merge After TollMulti-lane divided limited-access toll highways use “ramp tolls” and “barrier tolls”  
to collect tolls from motorists. A ramp toll is a collection mechanism at an  
entrance or exit ramp to the highway and these do not concern us here. A barrier  
toll is a row of tollbooths placed across the highway, perpendicular to the  
direction of traffic flow. There are usually (always) more tollbooths than there are  
incoming lanes of traffic (see former 2005 MCM Problem B). So when exiting the  
tollbooths in a barrier toll, vehicles must “fan in” from the larger number of  
tollbooth egress lanes to the smaller number of regular travel lanes. A toll plaza  
is the area of the highway needed to facilitate the barrier toll, consisting of the  
fan-out area before the barrier toll, the toll barrier itself, and the fan-in area after  
the toll barrier. For example, a three-lane highway (one direction) may use 8  
tollbooths in a barrier toll. After paying toll, the vehicles continue on their journey  
on a highway having the same number of lanes as had entered the toll plaza  
(three, in this example).  
Consider a toll highway having L lanes of travel in each direction and a barrier toll  
containing B tollbooths (B > L) in each direction. Determine the shape, size, and  
merging pattern of the area following the toll barrier in which vehicles fan in from  
B tollbooth egress lanes down to L lanes of traffic. Important considerations to  
incorporate in your model include accident prevention, throughput (number of  
vehicles per hour passing the point where the end of the plaza joins the Loutgoing traffic lanes), and cost (land and road construction are expensive). In  
particular, this problem does not ask for merely a performance analysis of any  
particular toll plaza design that may already be implemented. The point is to  
determine if there are better solutions (shape, size, and merging pattern) than  
any in common use.  
Determine the performance of your solution in light and heavy traffic. How does  
your solution change as more autonomous (self-driving) vehicles are added to  
the traffic mix? How is your solution affected by the proportions of conventional  
(human-staffed) tollbooths, exact-change (automated) tollbooths, and electronic  
toll collection booths (such as electronic toll collection via a transponder in the  
vehicle)?  
Your MCM submission should consist of a 1 page Summary Sheet, a 1-2 pageletter to the New Jersey Turnpike Authority, and your solution (not to exceed 20pages) for a maximum of 23 pages. Note: The appendix and references do notcount toward the 23 page limit.

问题B：收费后合并  
多车道有限接入收费公路使用“坡道收费”和“障碍收费”收取驾驶人士的收费。斜坡收费是一个收集机制入口或出口匝道到高速公路，在这里我们不关心这些。障碍收费是一排收费站横跨高速公路，垂直于交通方向。通常（总是）更多的收费的口比车道多（见之前2005年MCM问题B）。所以退出时收费站在通行费，车辆必须“扇入”从大量收费站出口车道到较少数量的常规旅行车道。收费广场是高速公路所需的便利通行费的区域，包括障碍物前的扇出区域，收费口障本身以及后面的扇入区域收费屏障。例如，三车道公路（一个方向）可以使用8收费站。在支付费用后，车辆继续他们的旅程在具有与进入收费广场相同数量的车道的高速公路上（在本示例中为三个）。考虑在每个方向上具有L个行驶车道的收费高速公路和障碍收费（B> L）。确定形状，大小和合并模式的区域跟随收费障碍车辆扇入B收费站出口线下至L车道的交通。

重要注意事项  
包括在您的模型包括事故预防，吞吐量（车辆每小时通过广场的末端加入L的点出行车道）和成本（土地和道路建设昂贵）。在特别的，这个问题不要求任何的性能分析特定的收费广场设计可能已经实施。关键是要确定是否有更好的解决方案（形状，大小和合并模式）任何常见的使用。确定您的解决方案在轻和重的流量的性能。如何您的解决方案随着更多自主（自驾）车辆添加而改变  
交通混合？你的解决方案如何影响常规的比例（人员）收费站，精确更换（自动）收费站和电子收费亭（例如通过转发器在电子收费站收集车辆）？您的MCM提交应包含1页的摘要表，1-2页给新泽西州收费公路局的信，以及您的解决方案（不超过20页面），最多23页。注意：附录和参考文献没有计数到23页的限制。

Problem C: “Cooperate and navigate”Traffic capacity is limited in many regions of the United States due to the number of lanes of roads.  
For example, in the Greater Seattle area drivers experience long delays during peak traffic hours  
because the volume of traffic exceeds the designed capacity of the road networks. This is particularly  
pronounced on Interstates 5, 90, and 405, as well as State Route 520, the roads of particular interest  
for this problem.  
Self-driving, cooperating cars have been proposed as a solution to increase capacity of highways  
without increasing number of lanes or roads. The behavior of these cars interacting with the existing  
traffic flow and each other is not well understood at this point.  
The Governor of the state of Washington has asked for analysis of the effects of allowing self-driving,  
cooperating cars on the roads listed above in Thurston, Pierce, King, and Snohomish counties. (See  
the provided map and Excel spreadsheet). In particular, how do the effects change as the  
percentage of self-driving cars increases from 10% to 50% to 90%? Do equilibria exist? Is there a  
tipping point where performance changes markedly? Under what conditions, if any, should lanes be  
dedicated to these cars? Does your analysis of your model suggest any other policy changes?  
Your answer should include a model of the effects on traffic flow of the number of lanes, peak and/or  
average traffic volume, and percentage of vehicles using self-driving, cooperating systems. Your  
model should address cooperation between self-driving cars as well as the interaction between selfdriving and non-self-driving vehicles. Your model should then be applied to the data for the roads of  
interest, provided in the attached Excel spreadsheet.  
Your MCM submission should consist of a 1 page Summary Sheet, a 1-2 page letter to theGovernor’s office, and your solution (not to exceed 20 pages) for a maximum of 23 pages. Note: Theappendix and references do not count toward the 23 page limit.Some useful background information:  
• On average, 8% of the daily traffic volume occurs during peak travel hours.  
• The nominal speed limit for all these roads is 60 miles per hour.  
• Mileposts are numbered from south to north, and west to east.  
• Lane widths are the standard 12 feet.  
• Highway 90 is classified as a state route until it intersects Interstate 5.  
• In case of any conflict between the data provided in this problem and any other source, use the  
data provided in this problem.  
Definitions:milepost: A marker on the road that measures distance in miles from either the start of the route or a  
state boundary.  
average daily traffic: The average number of cars per day driving on the road.  
interstate: A limited access highway, part of a national system.  
state route: A state highway that may or may not be limited access.  
route ID: The number of the highway.  
increasing direction: Northbound for N-S roads, Eastbound for E-W roads.  
decreasing direction: Southbound for N-S roads, Westbound for E-W roads

问题C：“合作和导航”  
由于道路的数量，美国许多地区的交通容量有限。  
例如，在大西雅图地区，由于交通量超过道路网络的设计容量，司机在交通高峰时段经历长时间的延误。这在5号，90号和405号州际公路以及520号国道，特别关注这个问题的道路上尤其明显。自动驾驶，合作车Self-driving, cooperating cars（我的理解是类似于顺风车，拼车的意思，）已被提出作为增加公路的能力而不增加车道或道路的数量的解决方案。在这一点上，这些汽车与现有交通流和彼此交互的行为尚未被很好地理解。

华盛顿州州长要求分析 允许在Thurston，Pierce，King和Snohomish县的上述道路上自行驾驶合作汽车的影响。 （Seethe提供的地图和Excel电子表格）。特别是，自动驾驶汽车的百分比从10％增加到50％到90％，效果如何变化？是否存在平衡？是否有性能变化明显的临界点？在什么条件下，如果有的话，应该有车道专用于这些车？您对模型的分析是否表明有任何其他政策变化？您的答案应包括对车道数量，峰值和/或平均交通量的交通流量的影响的模型，以及使用自动驾驶，合作系统的车辆的百分比。您的模型应该解决自驾车之间的合作以及自驱动车辆和非自驾车辆之间的交互。您的模型应该应用于的道路的数据  
利息，在附加的Excel电子表格中提供 一些有用的背景信息：

平均而言，每日交通量的8％发生在高峰旅行时间。

所有这些道路的名义速度限制为每小时60英里。

里程数从南到北，从西到东。

车道宽度是标准的12英尺。

高速公路90被分类为状态路线，直到它与州际5相交。

如果此问题中提供的数据与任何其他来源之间存在冲突，请使用

这个问题提供的数据。

定义：

milepost：在路上测量距离，从路线的起点或a

状态边界。

平均每日交通量：在道路上行驶的平均每天的汽车数量。

州际公路：作为国家系统的一部分的有限进出高速公路。

国家路线：可能受限或不受限制的国家公路。

路由ID：高速公路的编号。

增加方向：N-S道北行，E-W道东行。

下降方向：N-S道南行，E-W道西行

**Problem D: Optimizing the Passenger Throughput at an Airport Security  
Checkpoint**Following the terrorist attacks in the US on September 11, 2001, airport security has  
been significantly enhanced throughout the world. Airports have security checkpoints,  
where passengers and their baggage are screened for explosives and other dangerous  
items. The goals of these security measures are to prevent passengers from hijacking or  
destroying aircraft and to keep all passengers safe during their travel. However, airlines  
have a vested interest in maintaining a positive flying experience for passengers by  
minimizing the time they spend waiting in line at a security checkpoint and waiting for  
their flight. Therefore, there is a tension between desires to maximize security while  
minimizing inconvenience to passengers.  
During 2016, the U.S. Transportation Security Agency (TSA) came under sharp criticism  
for extremely long lines, in particular at Chicago’s O’Hare international airport. Following  
this public attention, the TSA invested in several modifications to their checkpoint  
equipment and procedures and increased staffing in the more highly congested airports.  
While these modifications were somewhat successful in reducing waiting times, it is  
unclear how much cost the TSA incurred to implement the new measures and increase  
staffing. In addition to the issues at O’Hare, there have also been incidents of  
unexplained and unpredicted long lines at other airports, including airports that normally  
have short wait times. This high variance in checkpoint lines can be extremely costly to  
passengers as they decide between arriving unnecessarily early or potentially missing  
their scheduled flight. Numerous news articles, including [1,2,3,4,5], describe some of  
the issues associated with airport security checkpoints.  
Your Internal Control Management (ICM) team has been contracted by the TSA to  
review airport security checkpoints and staffing to identify potential bottlenecks that  
disrupt passenger throughput. They are especially interested in creative solutions that  
both increase checkpoint throughput and reduce variance in wait time, all while  
maintaining the same standards of safety and security.  
The current process for a US airport security checkpoint is displayed in **Figure 1**.  
• **Zone A:**o Passengers randomly arrive at the checkpoint and wait in a queue until a  
security officer can inspect their identification and boarding documents.  
• **Zone B:**o The passengers then move to a subsequent queue for an open screening  
line; depending on the anticipated activity level at the airport, more or less  
lines may be open.  
o Once the passengers reach the front of this queue, they prepare all of  
their belongings for X-ray screening. Passengers must remove shoes,  
belts, jackets, metal objects, electronics, and containers with liquids,  
placing them in a bin to be X-rayed separately; laptops and some medical  
equipment also need to be removed from their bags and placed in a  
separate bin.  
o All of their belongings, including the bins containing the aforementioned  
items, are moved by conveyor belt through an X-ray machine, where  
some items are flagged for additional search or screening by a security  
officer (Zone D).  
o Meanwhile the passengers process through either a millimeter wave  
scanner or metal detector.  
o Passengers that fail this step receive a pat-down inspection by a security  
officer (Zone D).  
• **Zone C:**o The passengers then proceed to the conveyor belt on the other side of  
the X-ray scanner to collect their belongings and depart the checkpoint  
area.  
**Figure 1:** Illustration of the TSA Security Screening Process.  
Approximately 45% of passengers enroll in a program called Pre-Check for trusted  
travelers. These passengers pay $85 to receive a background check and enjoy a  
separate screening process for five years. There is often one Pre-Check lane open for  
every three regular lanes, despite the fact that more passengers use the Pre-Check  
process. Pre-Check passengers and their bags go through the same screening process  
with a few modifications designed to expedite screening. Pre-Check passengers must  
still remove metal and electronic items for scanning as well as any liquids, but are not  
required to remove shoes, belts, or light jackets; they also do not need to remove their  
computers from their bags.  
Data has been collected about how passengers proceed through each step of the  
security screening process. Click here to view the Excel data.  
Your specific tasks are:  
a. Develop one or more model(s) that allow(s) you to explore the flow of  
passengers through a security check point and identify bottlenecks. Clearly  
identify where problem areas exist in the current process.  
b. Develop two or more potential modifications to the current process to improve  
passenger throughput and reduce variance in wait time. Model these changes to  
demonstrate how your modifications impact the process.  
c. It is well known that different parts of the world have their own cultural norms that  
shape the local rules of social interaction. Consider how these cultural norms  
might impact your model. For example, Americans are known for deeply  
respecting and prioritizing the personal space of others, and there is a social  
stigma against “cutting” in front of others. Meanwhile, the Swiss are known for  
their emphasis on collective efficiency, and the Chinese are known for prioritizing  
individual efficiency. Consider how cultural differences may impact the way in  
which passenger’s process through checkpoints as a sensitivity analysis. The  
cultural differences you apply to your sensitivity analysis can be based on real  
cultural differences, or you can simulate different traveler styles that are not  
associated with any particular culture (e.g., a slower traveler). How can the  
security system accommodate these differences in a manner that expedites  
passenger throughput and reduces variance?  
d. Propose policy and procedural recommendations for the security managers  
based on your model. These policies may be globally applicable, or may be  
tailored for specific cultures and/or traveler types.  
In addition to developing and implementing your model(s) to address this problem, your  
team should validate your model(s), assess strengths and weaknesses, and propose  
ideas for improvement (future work).  
*Your ICM submission should consist of a 1 page Summary Sheet and your solution  
cannot exceed 20 pages for a maximum of 21 pages. Note: The appendix and  
references do not count toward the 20 page limit.***References:**[1] http://www.wsj.com/articles/why-tsa-security-lines-arent-as-bad-as-youd-feared-  
1469032116  
[2] http://www.chicagotribune.com/news/ct-tsa-airport-security-lines-met-20160823-  
story.html  
[3] http://www.cnn.com/2016/06/09/travel/tsa-security-line-wait-times-how-long/  
[4] http://wgntv.com/2016/07/13/extremely-long-lines-reported-at-chicago-midwayairports-tsa-checkpoint/  
[5] <http://www.cnbc.com/2016/04/14/long-lines-and-missed-flights-fuel-criticism-of-tsascreening.html>

问题D：在机场安全检查站优化乘客吞吐量  
  
2001年9月11日美国发生恐怖袭击事件之后，机场安全问题  
在世界各地得到显着增强。机场有安全检查站，  
其中乘客和他们的行李被筛选用于爆炸物和其他危险物品。这些安全措施的目的是防止乘客劫持或摧毁飞机，并在旅行期间保持所有乘客的安全。然而，航空公司有既得利益，通过最小化他们在安全检查站排队等候并等待他们的航班的时间，为乘客保持积极的飞行体验。因此，在希望之间存在最大化安全性同时最小化对乘客的不便的影响

在2016年，美国运输安全局（TSA）受到了对极长线路，特别是在芝加哥的奥黑尔国际机场的尖锐批评。在此公众关注之后，TSA投资对其检查点设备和程序进行了若干修改，并增加了在高度拥堵的机场中的人员配置。虽然这些修改在减少等待时间方面有一定的成功，但TSA在实施新措施和增加人员配置方面花费了多少成本尚不清楚。除了在O'Hare的问题，还有在其他机场，包括通常有短的等待时间的机场不明原因和不可预测的长线的事件。检查点线路的这种高差异对于乘客来说可能是极其昂贵的，因为他们决定在不必要地早到达或可能丢失他们的预定航班之间。许多新闻文章，包括[1,2,3,4,5]，（附件里有链接）描述了与机场安全检查站相关的一些问题

您的内部控制管理（ICM）团队已由TSA签订合同审查机场安全检查站和人员，以确定潜在的瓶颈扰乱旅客吞吐量。他们特别感兴趣的创意解决方案都增加了检查点吞吐量，减少了等待时间的方差维持相同的安全和保安标准。

您的内部控制管理（ICM）团队已由TSA签订合同审查机场安全检查站和人员，以确定潜在的瓶颈扰乱旅客吞吐量。他们特别感兴趣的创意解决方案都增加了检查点吞吐量，减少了等待时间的方差维持相同的安全和保安标准。  
  
美国机场安全检查点的当前流程如图1所示。  
·区域A：  
o乘客随机到达检查站，在队列中等待，直到a  
安全官员可以检查他们的身份证明和登机文件。  
·区域B：  
o乘客然后移动到随后的队列进行开放式筛选  
线;取决于机场的预期活动水平，或多或少  
线可以打开。  
o一旦乘客到达这个队列的前面，他们准备所有  
他们的物品X射线筛查。乘客必须删除鞋子，  
皮带，夹克，金属物体，电子器件和具有液体，  
将其放置在单独的X射线箱中;笔记本电脑和一些医疗  
设备也需要从他们的包里取出并放在一个  
单独bin.o他们的所有物品，包括包含上述的bin  
物品，由传送带通过X射线机移动，其中  
一些项目被标记为由安全性进行额外的搜索或筛选  
（D区）。  
o同时乘客通过毫米波进行处理  
扫描仪或金属检测器。  
o未能通过此步骤的乘客接受安全检查  
（D区）。  
·C区：  
o乘客然后前进到另一侧的传送带  
X射线扫描仪收集他们的物品并离开检查站  
区。

图1：TSA安全筛选过程的图示。

大约45％的乘客报名参加一个名为预检查的信任程序

旅客。这些乘客支付85美元接受背景检查，享受

单独筛选过程五年。通常有一个预检车道打开

每三个常规车道，尽管事实上更多的乘客使用预检

处理。预先检查乘客和他们的行李经过相同的筛选过程

设计了一些修改，以加快筛选。预检人员必须

仍然删除金属和电子物品扫描以及任何液体，但不是

需要去除鞋子，皮带或灯夹;他们也不需要删除他们

电脑从他们的袋子。

收集了关于乘客如何通过每个步骤的数据

安全检查过程。点击这里查看Excel数据。

您的特定任务是：

一个。开发一个或多个模型，允许您探索的流程

乘客通过安全检查点并识别瓶颈。显然

识别当前过程中存在的问题区域。

b。开发两个或多个可能修改的当前过程以改进

乘客吞吐量，减少等待时间的差异。将这些更改模型化

演示修改如何影响流程。

C。众所周知，世界各地都有自己的文化规范

塑造了社会互动的地方规则。考虑这些文化规范

可能会影响您的模型。例如，美国人深深地知道

尊重和优先考虑他人的个人空间，还有一个社会

耻辱在他人面前“切割”。同时，瑞士人也以此为名

他们强调集体效率，中国人被称为优先

个人效率。考虑文化差异如何影响方式

该乘客的过程通过检查点作为敏感性分析。的

文化差异适用于您的敏感性分析可以基于真实

文化差异，或者你可以模拟不同的旅行者风格

与任何特定文化（例如，较慢的旅行者）相关联。怎么可能

安全系统以加快的方式适应这些差异

乘客吞吐量并减少方差？

d。为安全管理人员提出政策和程序建议

基于您的模型。这些策略可以是全局适用的，也可以是全局适用的

针对特定文化和/或旅行者类型。

除了开发和实现你的模型来解决这个问题，你的

团队应验证您的模型，评估优势和弱点，并提出建议

改进想法（未来工作）。

您的ICM提交应包括1页摘要表和您的解决方案

不能超过20页，最多21页。注：附录和

引用不会计入20页的限制

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[5] <http://www.cnbc.com/2016/04/14/long-lines-and-missed-flights-fuel-criticism-of-tsascreening.html>