

Using AI to Solve Inspection Scheduling Problem for a Buying Office

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Abstract

This paper presents a project awarded by MGB HK to handle their inspection scheduling problem. MGB HK is the buying office of one of the largest retailers in the world, Metro Group. MGB HK handles all product procurement of Metro Group out of Europe. The inspection process is one of their critical processes along their entire procurement exercise. The objective of this project is to provide an effective scheduling engine so that in-house inspectors can handle as many inspections as possible using the least amount of time and costs. Meanwhile, we also help the company overcome their difficulties of data collection and maintenance as a result of the system we developed. Our engine will be deployed and integrated into the company's IMS. The engine recorded an improvement in the scheduling of their inspections and initial prognosis indicates that delayed inspections have been greatly reduced by compared with previous schedule. The system can effectively schedule inspections by urgency, shipment value, and supplier's historical performance. Other than the schedule, the AI engine can also generate solutions based on different strategies and criteria, which facilitate the decision-making process for the scheduling team and management at MGB HK.

Introduction

This paper is derived from a project awarded by Metro Group Buying Hong Kong (MGB HK). MGB HK is Metro

Group's buying office headquartered in Asia. Metro Group, the third largest retailer in the world, tasks MGB HK with the sourcing of diverse products, from textiles, to foodstuff and electrical appliances from over a thousand suppliers across Asia. These sourced products are subsequently imported to MGB HK's buyers in Europe. Additionally, MGB HK monitors every process in the buying procedure and coordinates all import/export activities with various parties.

The paper focuses specifically on addressing problems in the scheduling of inspections to appropriate in-house inspectors. In addition to applying our AI algorithm to generate the inspection schedule, we also developed an approach to collect and manage the operations data related to inspection activities, such as travel time, inspector performance and urgency of the inspection.

The scheduling of the inspection assignments is time critical and extremely important to MGB HK's supply chain management. Firstly, the Quality Control (QC) department typically conducts several thousand inspections per month. Secondly, the shipments of products are arranged immediately after inspection. If the products fail to meet expectations during an inspection, the shipment control department has to rearrange the affected shipments with the carriers. The re-inspection inevitably increases the operational time and costs. Therefore, the inspection process is an important aspect in MBG HK's procurement process to ensure shipment reliability.

Pre-existing Workflow

To manage their entire import/export process, MGB HK currently employs an Import Management System (IMS) that connects every in-house and external party along their supply chain; from sourcing, ordering, products inspection, logistics planning, to payment.

Specifically, MGB HK's typical workflow of scheduling inspections is largely manual. The process is initiated when a supplier submits an inspection request via the supplier's portal. Upon receiving a request, MGB HK's related departments proceed to review and validate the request, e.g. the administrative staff verifies if the import/export document is ready, the logistics staff contacts logistics service providers to make reservations, while the quality control administrator schedules all valid requests for inspection.

The impetus for adopting a manual scheduling approach stemmed from a cost saving perspective that simultaneously reduces the time on traveling as well as inspecting as many suppliers as possible. Hence, the allocation staff will first group the inspection tasks according to location. The staff then assigns the inspection schedule to a suitable in-house inspector. For example, while some inspectors only inspect textiles, others only inspect electrical appliances. There are still others who can inspect different combinations of products, e.g. there are inspectors whose repertoire include being able to inspect lighting and video/audio products. During the allocation process the staff has to communicate and negotiate all inspection arrangements.

Inspections are typically arranged every week after suppliers have booked their inspection dates through the portal. During non-peak seasons, inspection dates usually correspond to the dates booked by suppliers. During the peak seasons, however, some inspections are scheduled at most 3 days after the date requested by suppliers. This is mainly due to human resource limitations. Hence some inspections are inevitably outsourced to third-party inspection agencies, leaving MGB HK to bear the additional inspection costs and worse, scrambling for precious time to complete the inspections on time.

Project Objectives

Although MGB HK's pre-existing approach was relatively easy to implement, the inspection arrangement suffered from operational inefficiencies and may have sacrificed ease of planning for low service levels since the allocation staff could not optimally take into consideration the variations of inspection criteria, the complexity of the Travelling Salesmen Problem (TSP) (Gutin and Punnen 2002) and/or the Vehicle Routing Problem (VRP) (Solomon 1987, Bräysy and Gendreau, 2005ab).

The objective of this project is to provide an efficient scheduling plan for MGB HK that simultaneously achieves a better service level. An intelligent inspector scheduling system was subsequently developed by our team to achieve this goal.

We began by first segregating the project into two problems, namely into development of the scheduling engine and operations data maintenance. The scheduling problem (Pinedo 2008) is without doubt well studied. Many theory and effective algorithms have been developed to solve such operational problems. On the other hand, although software programs speed up the process to generate inspection schedules, the accuracy and efficiency of a schedule plan are largely dependent on the accuracy of the operations data. Unfortunately, collecting accurate operations data is not only a costly affair, it is also time consuming.

To solve this problem, our team designed and developed an approach to estimate the time required for the two main activities of inspectors, which are inspection and traveling. The inspection time largely depends on the quantity and type of products for inspection and inspector experience. The travel time is harder to estimate and differs greatly from city to city because of varying traffic conditions in the various Asian countries. To solve this part of the problem, we designed an intelligent engine that aims to maintain the accuracy of the operations data.

Application Description

The main purpose of the system is to facilitate the scheduling process. Besides a general querying function to retrieve inspection information, the application supports two main functions, namely, generating the inspection schedule and storing the "experience" of each inspection from each inspection visit. The user can easily generate an inspection schedule by setting a series of parameters for each inspection request, such as the maximum working hours and the required inspector skill set. After each inspection, users can also upload data from each inspection process as feedback that refines the accuracy of the operations data.

In addition, we had to take into account the integration of the scheduling application into MGB HK's IMS as it is the information backbone of their supply chain management process and users requiring the scheduling system include the company's management and staff of QC department. In order to minimize the integration effort, we concurred that developing an independent application and adding it as a component into the IMS would be the most efficient means to this end. This component, on the other hand, must then be able to communicate with the IMS and retrieve pertinent data regarding scheduling.

System Design

Once we understood the workflow of the inspector scheduling and related processes, we decided on applying a typical 3-tier implementation (Reese 1997), namely the front-end UI, the business tier and the database. The front-end web-based UI manages the interactions with users, user access, generates the scheduling reports, uploads the inspection results, and scheduling queries. The business

tier, developed using Java, consists of the scheduling and self-learning engine. Last but not least, the database contains all inspection-related data. The system architecture is shown in Figure 1.

In the early stages of our development, we wanted to simplify the integration and maintenance work. Hence, we duplicated a copy of enterprise's database. After the system was fully operational, the duplicated database was then migrated to the enterprise database.

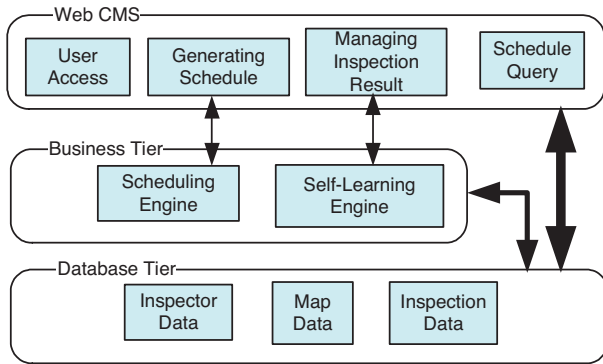


Figure 1: System Architecture

Generating Inspection Schedules

In this subsection, we briefly describe how staff from the QC department generates inspection schedules using the Inspection Scheduling System (ISS) we designed. First, a valid inspection request is uploaded through the excel worksheet format downloaded from the IMS. The data is then entered into the scheduling system which is built upon a content management system (CMS). The staff is then able to commence a step-by-step process using the scheduling system where the CMS will show the page for the parameters setting, such as high priority inspection. Once the parameters are set, users can click “run” to invoke the scheduling engine and subsequently generate the scheduling report.

Managing Inspection Data and Result

As we mentioned, the estimated inspection and travel times differ significantly as a result of the various professional and geographical constraints. The system provides a self-learning engine to maintain the operations data. Managing the inspection data is quite easy. First, the user uploads the inspection results to the ISS. Then the system will compare the inspection results with the operations data already in the database. (For details of our self-learning algorithm, please refer to the next section titled “Methodology”). Users can update the data via the system.

Figure 2 shows the overall workflow for generating inspection schedules and managing the operations data.

Methodology

The segment describes the methodology adopted in the design and development of our scheduling algorithm as well as the data maintenance module.

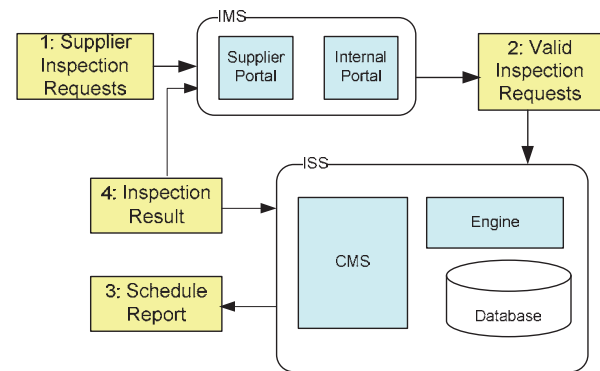


Figure 2: Overall Work flow of inspection scheduling

Formulation of the problem

The manual approach to scheduling was too simplistic and could not take into consideration of the various scheduling constraints. Other than spending less time on travel, they had to factor the importance or urgency of an inspection request. Let us consider a possible situation where certain products are of higher value, and logically, the operations costs are proportionally higher. In the event of inspection delays, MBG HK are pressed to incur more costs as necessary to rearrange shipments and warehousing due to the initial inspection delay. This has a domino effect on their costs structure. In worst case scenarios, buyers have even resorted to canceling the orders because of the delayed deliveries. Hence, curtailing delayed inspections is an imperative of MGB HK.

Unlike most of vehicle routing problems (Lim and Zhang 2006) which tried to minimize the number of vehicles used, our project has a fixed number of inspectors. Moreover, these inspectors cannot continuously travel or process jobs since each inspector has regular break intervals. Each inspector visits nodes and conduct inspections within a one week period, but he can only travel or conduct inspections during regular working hours(e.g., from 09:00 am to 6:00 pm). After each regular work period, the inspector must take a break. Regardless of an inspector's schedule, all inspection requests have to be done within a very specific time frame.

We summarize the problem as the follows:

Objectives

- Maximize the no. of inspections and the inspection value
- Maximize the no. of on-time inspections and on-time inspection value
- Minimize the travel time

And the objectives are subjected to the following:

- On each Monday, each inspector starts from the local office d_i after e_0 and stops inspections after l_0 ,
- Each inspection J_i has an associated service time q_i , and service time-window $[e_i, l_i]$
- For each day in a given scheduling period, every inspector works only during regular working hours. There is no inspection or travel after working hours.
- Inspection J_i can only be assigned to inspectors who have experience on that type of product.
- Each assigned trip cannot be interrupted.

Algorithm

The algorithm is proposed as a two-phased framework:

- Phase 1: Obtain an initial solution generation using a heuristic.
- Phase 2: Search neighbor of the initial solution to get better solution by Simulated Annealing (SA).

Initial solution Unlike most vehicle routing problems which minimize the vehicle number, our objective is to assign all inspection tasks as early as we can. The heuristic to generate the initial solution tries to assign at least one inspection request to each available and appropriate inspector.

SA Algorithm Simulation annealing algorithm (Kirkpatrick et al. 1983) is an effective search method which attempts to simulate the annealing process. The framework of SA algorithm is illustrated in Algorithm 1. Annealing process begins from a temperature T and continues to cool down until $T \leq 0$. For each temperature, a neighbor solution S' is generated. S' is accepted if $\Delta < 0$, where $\Delta = \text{Cost}(S') - \text{Cost}(S)$. Otherwise, S' will be accepted by a probability $e^{-\Delta/T}$ if $\Delta > 0$ which can allow the search to escape a local optimal.

The Simulated annealing algorithm used in this system is developed by Li and Lim 2002. In addition, we added a feasible solution checker to ensure the solutions fit the constraints we mentioned. This algorithm can be easily implemented, but also we can easily to replace and add in new operators in future, especially when new requirement comes from users.

In algorithm 2, p_a and p_b are the probabilities to use operators “Change” and “Shift” respectively. Basically, The Operator “Change” will insert a new inspection into a route of inspectors. The Operator “Shift” will shift a segment of a route of inspector r_i to r_j . The Operator “Exchange” will exchange the segment of route between r_i to r_j .

Objective and Cost function The objective of our problem is to maximize total inspection and on-time inspection times. Therefore, we have the following objective and cost function:

$$\text{Max} \left\{ \sum_i \{PV_i\} - \alpha_1 \sum_i \{PV_i \times DD_i\} \right. \\ \left. + \alpha_2 \sum_i \{PV_i \times ETD_i\} - \alpha_3 T(S) \right\}$$

- PV_i is the product value of inspection J_i
- DD_i is the no. of days after the inspection request
- ETD_i is the day before expected time to departure
- S is the inspection plan
- $T(S)$ is the Travel Cost of the inspection plan
- α_k is the weight of the cost factor, which can be adjusted on the system

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0. ALGORITHM. SA(Solution S)
1. Get an initial Solution S
2.  $S_{\text{Best}} \leftarrow S$ 
3.  $T \leftarrow$  an initial temperature
4. WHILE  $T > 0$  DO
4.1 WHILE NOT yet accept DO
4.1.1  $S' \leftarrow \text{GetNeighbor}(S)$ 
4.1.2  $\Delta \leftarrow \text{Cost}(S') - \text{Cost}(S)$ 
4.1.3 IF  $\Delta \leq 0$  THEN prob  $\leftarrow 1$ 
4.1.4 ELSE prob  $\leftarrow e^{-\Delta/T}$ 
4.1.5 IF random(0,1)  $\leq$  prob THEN
4.1.5.1  $S \leftarrow S'$ 
4.1.5.2 IF  $S$  is better than  $S_{\text{Best}}$  THEN  $S_{\text{Best}} \leftarrow S$ 
4.2  $T \leftarrow T - \Delta T$ 
5 RETURN  $S'$ 

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Algorithm 1: SA Algorithm

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0 ALGORITHM. GetNeighbor(Solution S)
1 WHILE NOT yet accept a neighbor  $S' \in N(S)$  DO
1.1  $r \leftarrow \text{random}(0,1)$ 
1.2 if ( $r < p_a$ )  $S' = \text{Change}(S)$ 
1.3 else if ( $r < p_b$ )  $S' = \text{Shift}(S)$ 
1.4 else  $S' = \text{Exchange}(S)$ 
1.5 if ( $S'$  is feasible) Accept  $S'$ 
2 RETURN  $S'$ 

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Algorithm 2: Neighbor Searching Algorithm

Data Collection and Self-learning

To generate an accurate inspection schedule, we need to have an accurate estimation of the travel and inspection times. However, they are also the most difficult aspects of the project.

Data collection is a time consuming and costly process. There are several reasons. Firstly, MGB HK's IMS did not require such data. No such data structure was ever defined in the IMS. Secondly, transportation times are uncertain and differ significantly from location to location. This is especially pronounced for MGB HK's suppliers as most of them are based in developing countries.

Therefore, we proposed an approach to collect the related travel data:

First, we developed a hierarchical structure consisting *location, Country, Province, City and Area*. Each supplier's base can be mapped to an area code. Meanwhile, we employed a cost-effective geographical system like Google Maps to calculate the center coordinates of each area.

Next, we asked the suppliers from various regional offices to provide rough travel times and classified them into *Within-Area Travel Time, Inter-Area Travel Time, Inter-City Travel Time, Inter-Province Travel Time, and Inter-Country Travel Time*.

Travel times can be used in normal cases. However, there are some conflicts in boundary cases. We illustrate Figure 3 as an example.

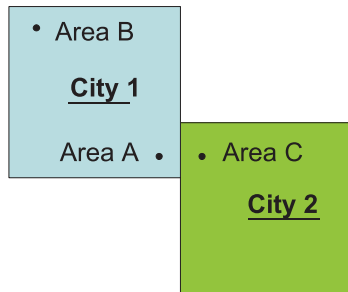


Figure 3 Example of the boundary case

Area A and Area B are in the City 1 grouping, whilst Area C is located in the City 2 grouping. However, the distance D_{ac} between Area A and C is shorter than the distance D_{ab} between Area A and B.

We proposed the following approach to update the travel times:

- If $D_{ab} \gg D_{city\ average}$, Travel Time is too long, T_{ab} will be updated.
- If $D_{ac} \ll D_{city\ average}$, Travel Time is too short, T_{ac} will be updated.

" $\gg$ " and " $\ll$ " mean much longer and much shorter respectively. The new travel time will be average travel time between two Area, e.g. $T_{ab} = V_{average} D_{ab}$

In summary, the user can apply this approach to collect and update the operations data to gain a better estimation on both the travel and inspection times. By using this approach, the operations data in the IMS database is constantly and gradually evolving to be even more accurate.

Application Use and Payoff

The system first underwent an acceptance testing stage. At this point, even though the system has not been officially deployed, the benefits of the project are already beginning to emerge.

At this stage, we can only provide the following rudimentary payoffs of the ISS as reverted to our team from the initial test bed (southern China):

Shortened Scheduling times

One of the initial benefits MBG HK enjoyed from the ISS is greatly shortened scheduling times. By clicking and selecting relevant parameters, the staff can easily generate appropriate scheduling plans, instead of spending time to coordinate and negotiate with the various parties.

Bridging the Gap between the IT and Operations

Previously, as the inspection scheduling process was too complicated to be handled by their IMS system. So all inspection data and experience could only be stored within the staff involved. As a result, there is a lack of fair performance measurement of the inspection services. During the design and development of the scheduling process, more accurate measurement and estimation on performance and operation, such as inspection and travel times, were also developed. This bridges the gap between MGB HK's IT system and its operations. Moreover, the management of MGB HK can now justify the capacity and performance of their inspection services.

Improved Quality of Service

With globalization, manual planning in any organization becomes virtually impossible. In MGB HK's case, their pre-existing strategy of grouping inspections by location to minimize traveling time, could only optimize the travel times but not factor in other constraints that critically affected their supply chain process. With this inspection scheduling system, their staff can now test various scenarios under different scheduling strategies to generate the most optimal scheduling plan to fulfill the various business requirements.

Reduced Internal Communication Effort

As a result of the system, the inspection team requires less communication with the scheduling staff and this saves time for their main task at hand - inspecting. Additionally, although inspection scheduling affects the operations cost, it is not the main focus or responsibility of the QC department. By using the inspection scheduling system, the department is thus relieved from the tedious and time consuming scheduling work. Furthermore, other departments along the supply chain also enjoy the trickling benefit of the enhanced service level of the QC Department, greatly reducing unnecessary negotiations, misunderstandings and complaints.

Adaptive to Business Change

MGB HK is a business like any other, where the business environment they face is ever changing, impacting their cost structures, rules and inspection priorities. From our perspective, the ISS is designed such that operational functions and operations data can be updated by their IT team and QC department to adapt to the various changes when appropriate.

Application Development and Deployment

This paper is the culmination of one of our consulting projects with MGB HK. The project kicked-off around the middle of 2008, which explains the lack of concrete benefits. However, it does not take away the fact that this project clearly demonstrates the capabilities of AI technology.

We have since passed through several testing stages together with MGB HK for this AI application development and are briefly described below:

Stage 1: Data Definition and Collection Different from general commercial applications which typically focus on process, our AI application enhances operational efficiency, flexibility and scalability.

After an in-depth analysis of the previous scheduling process as well as the operations data, we found that the data in the current IMS could not directly be used by the scheduling system. This situation usually occurs during development as operational problems were managed by the QC staff.

Then we re-defined the data we needed to develop the optimization engine. For example, inspection time is determined by the complexity of the product and inspection sampling size. However, this information was also managed by the QC staff.

For the traveling time estimation, we also faced a similar problem as above and proposed the approach to estimate the travel time and to maintain the operations data. (For details, please refer to the section Methodology)

Stage 2: Engine Development Once all parties understood the functional requirements we developed the application for the system sometime in November of 2008 Nov and completed the development this January.

Stage 3: Acceptance Testing and Deployment The system is now in the acceptance testing stage by the QC department. For the first phase of deployment, the system will slated to apply to inspections in southern China. In the second phases, the system will then be applied to the rest of China. The system will officially be deployed by Jul 2009.

Maintenance

The maintenance work will contain three aspects, namely the system, operations data, and the AI engine.

The hardware and software system maintenance works are managed by the IT team at MGB HK. The IT team will continually enhance the usability of the system. In addition, the IT team will also help in developing different scheduling strategies as we have provided very detailed documentation on the interface for setting the parameters for strategies.

The operations data work is maintained by the QC department. As it stands, the effort required for operations data maintenance is greatly minimized. The system will analyze the inspection results submitted by the inspector.

The staff can run the inspection results analysis function to retrieve and update any problem operations data.

Last but not least, team members from the City University of Hong Kong are responsible for the maintenance work of the AI engine that adapts the business requirement changes. As the system has only been deployed for inspection scheduling in Southern China, most of the business requirements are handled by the current engine.

Conclusion

In this paper, we presented an inspection scheduling system we have built for MGB HK. The system has shown that it can highly shorten the scheduling time as well as increase the effectiveness of their schedule plans to provide better service along their supply chain. The system is set to be deployed to manage the schedules of all inspection activities in China by Jul 2009.

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