Project register: Optimisation Group

Department of Industrial & Systems Engineering, University of Pretoria, South Africa

October 23, 2020

This document serves as a register of projects pursued by the Optimisation Group within the Department of Industrial and Systems Engineering. These include those projects with a particular emphasis on applying *data science*. The projects referred to in this document are at various stages of completion: some are still ideas worth considering for (mainly graduate) students; some are currently being pursued; and some are already completed.

For each project we provide a title, concise description, its current status, and the contact person (name & email address). If you have any questions, or are interested in getting involved in one of these projects, please contact the relevant person by clicking on the contact name of the project you are interested in. The fact that a project is *available* does not mean we have to (or will) allocate an interested student to it. We reserve the right to evaluate applicants to ensure a win-win-win (supervisor, project and student) situation.

Projects that are greyed out will be kept on the register for a while, but are not open for students anymore. Check frequently.

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083 Revisit activity chain extraction

Description: In one of our group's seminal works on activity chains, Joubert and Axhausen (2011) used the ignition on/off signal of a vehicle to identify the start and end of a trip. But there is other work like that of Cich et al. (2016) that I am interested in for a student to investigate. Working with a set of GPS traces, how different will the activity chains be if extracted using the approach by Cich et al. (2016) versus our original ignition-based approach? This project will expose the student to working with a nice large set of geospatial data and allow for interesting data analysis.

References:

Joubert, J. W. and Axhausen, K. W. (2011). Inferring commercial vehicle activities in Gauteng, South Africa. *Journal of Transport Geography*, 19(1):115–124

Cich, G., Knapen, L., Bellemans, T., Janssens, D., and Wets, G. (2016). Threshold settings for TRIP/STOP detection in GPS traces. *Journal of Ambient Intelligence and Humanized Computing*, 7(3):395–413

Contact: Johan W. Joubert

Status: Project assigned to Tumelo Koko for BCS in 2020

082 Multimodal long haul routing problem

Description: To deal with the multimodality in logistics, Wolfinger et al. (2018) introduced a (meta)heuristic that is based on a combination of the Service Network Design Problem (SNDP) and the Vehicle Routing Problem (VRP). This project will investigate their algorithm, and attempt to implement it as part of (or integrated with) the `jsprit` library used for the `freight` contribution within the Multi Agent Transport Simulation (MATSim) toolkit.

References:

Wolfinger, D., Tricoire, F., and Doerner, K. F. (2018). A matheuristic for a multimodal long haul routing problem. *EURO Journal on Transportation and Logistics*, 8(4):397–433

Contact: Johan W. Joubert

Status: Unassigned. Available to BPJ (less likely), BCS on MEng student.

081 Vehicle-specific emissions in Gauteng

[git] • Branch: master @ a464f88 • Author: Johan W. Joubert • Date: 2020-08-17 13:26:38 +0200 •

Description: This project builds on 050. Using the available MATSim data, based on the origin-destination matrices of the SANRAL model, determine the emissions contributed to light and heavy vehicles. To do this, the candidate should look into the vehicle fleet in Gauteng

Contact: Johan W. Joubert

Status: Assigned to Ruan Gräbe to work on in both BUY 780 and BCS 780.

080 How to optimise block time in airline operations?

Description: It is important to predict the block time in future based on a Day of week, time of day. This must include Financial analysis. Taxi times per airport, by day and times of the day as well as its implications.

If applying for the BCS 780 module, competence in either BOZ 780, BAR 780 or BUY 780 is required. **Students interested in this topic as a BCS project must first arrange a consultation and must submit a resumé and 500 word motivation.**

Contact: Wilna L. Bean

Status: Currently unavailable pending SAA-UP NDA.

079 Reduce Food wastage by optimising the ordering process.

Description: Buying, making and loading food have to be done well in advance without having final passenger numbers. Some of our fights booking window is 3 days in advance making it difficult to predict the correct loads. Building a model to optimise the food preparation based on changing passenger numbers. If applying for the BCS 780 module, competence in either BOZ 780, BAR 780 or BUY 780 is required. **Students interested in this topic as a BCS project must first arrange a consultation and must submit a resumé and 500 word motivation.**

Contact: Wilna L. Bean

Status: Currently unavailable pending SAA-UP NDA.

078 Delay predictions in airline operations

Description: Irregular operations are a major cost element of SAA. If we can predict the delays based on Time of Day, week, month, connections, etc. We can better manage the cause of the delays. The research will go on how to build a model to predict delays.

If applying for the BCS 780 module, competence in either BOZ 780, BAR 780 or BUY 780 is required. **Students interested in this topic as a BCS project must first arrange a consultation and must submit a resumé and 500 word motivation.**

Contact: Wilna L. Bean

Status: Currently unavailable pending SAA-UP NDA.

077 Quantify the impact of a currency movements on airlines in South Africa

Description: Airlines in South Africa interact with, and can be affected by overseas markets in a number of different ways; be it selling tickets (direction of traffic) importing equipment/ parts for MRO or purchasing jet fuel. In many circumstances, this will involve paying in foreign currency or receiving revenue in foreign currency and therefore exposing the airlines to currency fluctuations. This will include implications like direction of travel (driven by tourism/business). There also need to be looked at the timing (e.g. future sales vs short term payment impact)

If applying for the BCS 780 module, competence in either BOZ 780, BAR 780 or BUY 780 is required. **Students interested in this topic as a BCS project must first arrange a consultation and must submit a resumé and 500 word motivation.**

Contact: Wilna L. Bean

Status: Currently unavailable pending SAA-UP NDA.

076 Determine the Airline's Cost of Minute delay (Operational Costs)

Description: The Airlines key function is to ensure that the airline schedule is flown to the published schedule however due to variable reasons the schedule differs from what was planned. This comes at a cost which is scattered throughout the organisation. It is therefore imperative for the airline to have full view and understanding of the overall financial impact in relation to flight delays and operational recovery. In streamlining operations processes, it is important to focus on developing a scientific model to calculate the actual costs associated with delays (i.e. ground and airborne) and to ensure flights are always on time with minimal financial impact.

If applying for the BCS 780 module, competence in either BOZ 780, BAR 780 or BUY 780 is required. **Students interested in this topic as a BCS project must first arrange a consultation and must submit a resumé and 500 word motivation.**

Contact: Wilna L. Bean

Status: Currently unavailable pending SAA-UP NDA.

075 Hub bypass — Impact of hub bypass on class and gauge of travel

Description: Legacy Carriers and Long Haul Low Cost Carriers are increasingly offering direct services to other cities within Southern Africa and therefore bypassing our Johannesburg hub. The introduction of more efficient aircraft in relation to economic growth and urbanisation may also create new opportunities for airlines to operate in certain markets directly instead of via a hub. This research should look at the impact that this hub bypass has on travel patterns. If applying for the BCS 780 module, competence in either BOZ 780, BAR 780 or BUY 780 is required. **Students interested in this topic as a BCS project must first arrange a consultation and must submit a resumé and 500 word motivation.**

Contact: Nadia M. Trent

Status: Assigned as internal research project

074 Customer Lifetime Value (CLV) Formula for SAA Voyager

Description: The available CLV formulas are simplistic in nature for customer loyalty programmes in general but are however not suitable for a typical frequent flyer programme. Since SAA might consider strategic equity partnerships, the CLV of SAA Voyager is a frequently asked question to determine the Customer Equity (CE), deemed by investors as a sustainability measure for investment appraisals. An interested student must have a strong affinity for quantitative projects and coding. If applying for the BCS 780 module, competence in either BOZ 780, BAR 780 or BUY 780 is required. **Students interested in this topic as a BCS project must first arrange a consultation and must submit a resumé and 500 word motivation.**

Contact: Wilna L. Bean

Status: Currently unavailable pending SAA-UP NDA.

073 Dynamic marginal contribution updating

Description: When receivers and carriers collaborate, the current MATSim implementation only calculates each receiver's marginal contribution (in a game theoretic setting) at the start of the simulation run. However, as the simulation progresses, the state space changes. That is, receivers adjust their order frequency, time windows, and service times. As a result, their true (marginal) contribution to the carrier's cost changes. In this project the candidate should implement the (re)calculation of the marginal contribution during the progression of the overall simulation run.

Contact: Johan W. Joubert

Status: Available for MEng and PhD students

072 Carrier pricing

Description: When a carrier decides on a pricing structure, it is set up in a way that receivers close to the depot will likely subsidise those further afield. This project will investigate and study such pricing structures and, possibly, embed it in a behavioural model in MATSim.

Contact: Johan W. Joubert

Status: Available for MEng and PhD students

071 Adjusted proportional cost allocation

Description: Building on the PhD thesis of Mrs Wilna Bean, this topic will investigate the effect of *adjusted* proportional cost allocation on the collaboration between freight carriers and receivers.

Contact: Johan W. Joubert

Status: Available for MEng and PhD students

070 Re-evaluation of lecture venue allocations

Description: The higher education environment in general, and the University of Pretoria specifically, has changed quite significantly. One consequence of the language policy is that lecture room requirements are changing. This project will deal with a data scientific evaluation of the current status of, and needs for venue allocation. The project will entail dealing with large amounts of student registration data, and evaluating the current process of allocating modules to lecture halls. The goal is to provide decision-support to the University's Department of Facilities Management on what lecture hall sizes the University should plan for in the (near) future. The project will require a strong competence in data science, programming (preferably in R), and general industrial analysis techniques. Mathematical programming (Operations Research) will also be required.

Contact: Johan W. Joubert

Status: Withdrawn by Department of Facilities Management.

069 The social network of complex network theory scientists

Description: Your life is full of social networks: your family, your UP friends, your Instagram empire, your Fortnite collaborators. For a few decades now scientists have been using concepts from complex network theory to capture, model and study such social networks. Who is the most famous in the network? Who is the linchpin? Who is the one with fingers in every pie? What do the sub-communities look like? This approach to studying social structures has been applied widely: epidemiology, criminology, innovation networks, marketing, and... citation networks. The best way to discover who-knows-who and who's who in the zoo among researchers is to track how they cite each other's work. This project will map and analyse the citation network of nearly 300 published journal and conference articles in the domain of complex network theory applications in transportation. An interested student must have a strong affinity for quantitative projects and coding. If applying for the BCS 780 module, competence in either BOZ 780 or BAR 780 is required.

Contact: Nadia M. Viljoen

Status: Assigned to Kobus Rust for his MIT mini-thesis. In final examination phase

068 Categorising truck behaviour based on GPS-based activity chaining and land use data in the City of Cape Town

Description: We can learn a lot from the anonymous GPS traces of commercial vehicles. We can see when they were on or off, where they travelled and when they travelled there. Using activity chaining and density-based clustering algorithms we can dig even deeper to determine when and where vehicles were executing logistics activities and the location of the most prominent logistics facilities in an area. But there are many things we cannot (yet) tell: type of vehicle, industry served, whether the vehicle was loaded or empty etc. This project will scrutinise the activity chain patterns of vehicles moving in the City of Cape Town along with land use data to determine the behavioural trends that could help in filling in some of the "unknowns" of this anonymous data. An interested student must have a strong affinity for quantitative projects and coding. If applying for the BCS 780 module, competence in either BOZ 780 or BAR 780 is required.

Contact: Johan W. Joubert

Status: Unassigned. Project available as a BCS 780 topic only to a student who is intent on completing their Masters degree.

067 Development of a residential property investment evaluation tool for the South African market.

Description: Residential property investment is a popular investment choice made by many South Africans. Having said that, many economists and investment specialists have a pessimistic view on this investment vehicle. Firstly, investors are often swayed by single statistics or rudimentary calculations of profitability. Secondly, they do not consider the variability in the market factors that influence profitability. This project blends data science, financial feasibility models and an appreciation of market forces to develop a decision support tool for an investor wishing to invest in residential property. The student must have a strong affinity for quantitative projects and engineering economics. For BPJ applicants, competence in BAN 313 is required while competence in BIE 420 is preferential. For BCS 780 applicants, competence in both BAN 310 and BIE 420 is required.

Contact: Nadia M. Viljoen

Status: No longer available

066 Development of a national freight flow network model for the South African grain industry

Description: Maize and wheat are two critical commodities in the South African economy. Not only are both these commodities foundational to food security, they also constitute a large portion of imports and exports. Transport inefficiencies in the agricultural sector erode South Africa's competitiveness. In order to investigate the potential of a host of interventions, stakeholders first need an accurate representation of how wheat and grain *flow* in the South African economy. This project collaborates with Agbiz Grain, GRAIN SA and SAGiS to develop such a freight flow network model for wheat and maize. Concepts from complex network theory and network optimisation will be required in this project. The student must have a strong affinity for quantitative projects and coding. Competence in undergraduate BAN, BOZ and BUY is essential if taken as a BPJ project. If applying for the BCS 780 module, competence in either BOZ 780 or BAR 780 is required.

Contact: Nadia M. Viljoen

Status: Completed by Brian Milne BPJ 2019

065 Spatial matching of logistics facilities in a longitudinal dataset

Description: Start with the GPS traces of tens of thousands of commercial vehicles, run these through activity chaining and density-based clustering algorithms and you can identify logistics facilities in South Africa. But what if you repeat the same process with next month's or next year's data? Will your algorithms identify exactly the same facilities with exactly the same centroids and polygons? Certainly not. How will you then know whether two unique yet similar polygons refer to the same facility? This project will design, execute and test an algorithm that can identify similar logistics facilities in longitudinal datasets. An interested student should be advanced in quantitative methods and coding. For a BPJ project, competence in undergraduate BAN and BOZ is prerequisite. If applying for a BCS 780 project the student must be intent on continuing this topic in his/her Masters degree and must be competent in either BAR 780 or BOZ 780.

Contact: Nadia M. Viljoen

Status: Completed by Andrii Burkat BPJ 2019

064 Discover, model and assess the air-road freight value chain at OR Tambo International Airport (ORTIA)

Description: In this project a student will work with the Airports Company South Africa (ACSA) and various freight forwarders around the OR Tambo International Airport to discover, model and assess the current state of the air-road freight value chain at ORTIA. This project is not primarily quantitative in nature but will require an extraordinary amount of initiative, creativity, tenacity and people skills for a successful student to interact with all the stakeholders involved. The end-goal of this project is to construct a network graph of all the players in the value chain and (potentially) quantify the volumes that flow in this network. Many hours will be spent at ORTIA

and some of their freight stakeholders and because of this requirement this project is not suitable as a BCS 780 topic.

Contact: Nadia M. Viljoen

Status: Completed by Thomas Weeks BPJ 2019

063 Modelling carrier vehicle restrictions at receiver facilities in MATSim

Description: Due to space limitations, receivers often set size restrictions for delivery vehicles accepted at their facilities in urban areas. Unfortunately the existing `freight` contribution of the Multi-Agent Transport Simulation (MATSim) toolkit does not allow receiver agents to set restrictions on the carrier vehicles sizes allowed for deliveries at their facilities. This project will therefore focus on expanding the receiver (and possibly carrier) agent infrastructure in the MATSim `freight` contribution to allow receivers to set vehicle restrictions for deliveries at their facilities; and testing/illustrating the functionality with a case study. The project will require knowledge of Java and MATSim.

Contact: Wilna L. Bean

Status: Withdrawn. Project completed in-house.

062 Multi-day runs in MATSim

Description: The existing Multi-Agent Transport Simulation (MATSim) infrastructure does not accommodate multi-day runs, resulting in unintentional order frequency decisions by freight receivers during reordering. Introducing multi-day simulation runs into MATSim and running simulations over a five day work week could provide a way to more accurately capture the effects of receiver delivery frequency preferences on other freight agents' logistics behaviour. Therefore this project focuses on expanding MATSim to include multi-day runs and testing the functionality with a realistically sized problem. This will enable the more accurate modelling of the effects of delivery frequency on carrier delivery cost in MATSim. The project will require knowledge of Java and MATSim.

Contact: Johan W. Joubert

Status: Project allocated to Mr Paul Jacobs for BPJ in 2020.

061 Pickup points placement

Description: Use the `freight` contribution of the Multi-Agent Transport Simulation (MATSim) toolkit to study the effect of pickup points or parcel boxes as a more secure and cost-efficient for last-mile delivery, especially online shopping and parcel deliveries. The more parcel boxes we have, the lower the delivery density (parcels delivered per location) for the carrier, not justifying the cost. On the other side, if the parcel boxes are too far apart, it will necessitate a private car trip that would otherwise have been avoided. Currently, Ms Elizna Cilliers is investigating the impact of pickup points on carrier delivery cost as a part of her masters degree, however, the impact of pickup point location on passenger movements is excluded from her analysis.

Following Joubert (2018) we have the benefit to also include the population density, and demographics in evaluating the placement of these parcel boxes from a combined passenger and freight movement perspective. The project will require knowledge of Java and MATSim.

References:

Joubert, J. W. (2018). Synthetic populations of South African urban areas. *Data in Brief*, 19:1012–1020

Contact: Johan W. Joubert

Status: Unassigned. Project available to BPJ (with existing MATSim experience), BCS 780 or MEng student.

060 Container (de)stuffing

Description: Use the `freight` contribution of the Multi-Agent Transport Simulation (MATSim) toolkit to study the effect of container (de)stuffing at, or close to the port. Often containers are

destuffed in that they are opened and repacked into curtain-sided, interlink trucks since the curtain-sides trucks has a higher load factor than one-container-per-vehicle. This introduces handling (and its associated risk), and time to the supply chain? How (and why) is this beneficial? The project will require knowledge of Java and MATSim, and will entail setting up and testing a small-scale scenario.

Contact: Johan W. Joubert

Status: Unassigned. Project available to BPJ (with existing MATSim experience), BCS 780 or MEng student.

059 Dealing with multi-access points for freight deliveries

Description: Consider two use cases. Firstly, a distribution centre like that of Shoprite may only see vehicle entering from Brakfontein Rd, while vehicles exits the premises through Olievenhoutbosch Rd. Secondly, a shopping center like Brooklyn Mall may be serviced from multiple roads: some heavy vehicles may use the back door entrances at either Bronkhorst St or Middel St, while smaller vehicles may access the mall through any one of the parking entrances. The objective of this project is to find a solution on how such instances will be handled in the `freight` contribution of the Multi-Agent Transport Simulation (MATSim) toolkit, since there each facility is only associated with a single link. this project will require some background in MATSim, or a willingness to learn MATSim, and Java, the programming language of MATSim.

Contact: Johan W. Joubert

Status: Unassigned. Project available to BPJ (with existing MATSim experience) or BCS 780 students.

058 Developing network examples for experimentation in MATSim

Description: This project focuses on investigating various network examples used previously to perform experiments in MATSim (a multi-agent transport simulation platform implemented in Java), and developing and testing a few network examples that can be used for experimentation in MATSim. A basic knowledge of Java programming and MATSim would be required.

Contact: Wilna L. Bean

Status: Project withdrawn.

057 Heuristic growth model in complex networks

Description: Existing methods exist to generate graph networks that represent typical network applications that are known to follow, at least partially, power laws. But many of these generation and growth models are quite cumbersome and computationally quite inefficient. In this project the candidate should familiarise her/himself with the current state of the art in terms of network growth models, and implement a (meta)heuristic alternative that is computationally efficient for large instances.

Contact: Johan W. Joubert

Status: Withdrawn. This is a duplication of project 039.

056 Self-regulation in taxi despatches

Description: The paratransit mode, better known as *minibus taxis* in South Africa, are notorious to not leave the rank areas unless the occupancy is above some minimum threshold. But if a driver was to know more accurately what the likelihood is of picking up passengers en route, how much better would the waiting time be for commuters (onboard and along the route). In this project the candidate should establish small scale yet realistic experiments to test this phenomena, assuming different levels of *a priori* knowledge available to the driver. It is anticipated that the candidate develops a self-organising scheme that is a good trade-off between waiting time (for the commuter) and profitability (for the driver) over the course of a day. It is anticipated that the model will be developed in *AnyLogic* while MATSim might be an alternative.

The impact of constant-headway as a metric could be evaluated

Contact: Johan W. Joubert

Status: Initial literature review completed by Mr Ruan van Loggerenberg (BCS 780 in 2018). Follow-up modelling aimed at M.Eng or PhD level, depending on the scope

055 Performance evaluation of simple routing heuristics

Description: Following on project (006) below this project aims to implement basic routing heuristics, like a sweeping arc, into MATSim's `freight` contribution and evaluate its computational performance as well as its generalised cost performance when congestion is also accounted for. That is, the question the candidate should aim to answer is *'how much better do advanced scheduling procedures perform against simple heuristics amidst uncertain travel times'*. A fair knowledge of Java programming would be required.

Contact: Johan W. Joubert

Status: Available as BCS 780, M.Eng, or PhD project.

054 'Let's take a drive'

Description: Model leisure travel in the agent-based MATSim. The candidate should establish what the actual extent is of people's driving habits when it comes to driving *for the sake of driving*. How is this portion of travel demand established and estimated? What routes are people frequenting for this purpose? What data is available, or necessary, to be able to model this in MATSim?

Contact: Johan W. Joubert

Status: Available as M.Eng, or PhD project.

053 Modularisation of cargo

Description: If more cargo can be packaged in standard configurations, for example the current 10 ft, 20 ft or 40 ft containers, what are the efficiency gains to be had on system-wide level? This project aims to implement this in MATSim and its `freight` contribution and test (futuristic) opportunities for load-consolidation: last-mile delivery via *automated cargo* units, as but one example. A basic/fair knowledge of Java programming would be required.

Contact: Johan W. Joubert

Status: Available as BCS 780, M.Eng, or PhD project.

052 Evaluate flexi-work options in MATSim

Description: Allowing employees to work flexible hours is one initiative considered in alleviated peak-period congestion. This project aims to test that policy in the agent-based MATSim. A basic/fair knowledge of Java programming would be required.

Contact: Johan W. Joubert

Status: Project allocated to Ms Nadine Smal for BPJ in 2020. The project forms part of Mr Gerhard Hitge's PhD work.

051 Test a freight ban in an agent-based transport model

Description: One of the popular options for transport policy makers is to consider freight bans (prohibiting freight vehicles on certain areas of the road network) as a possible solution to alleviate congestion, especially in the peak periods. But there is little evidence of the true impact, and more seriously, the unintended consequences it will have. This project aims to implement and test truck bans in MATSim, along with its `freight` contribution. A basic/fair knowledge of Java programming would be required. Some experience in MATSim is highly recommended.

Contact: Johan W. Joubert

Status: Project assigned to Mr Neacail Hilhorst as a BPJ final year project in 2019.

050 Emissions modelling in MATSim

Description: This project aims to develop a use case of the `emissions` contribution in the agent-based MATSim. That is, choose an area where a current South African MATSim implementation exist and extend it to also capture the vehicles' emissions. Also, the candidate would be expected to test a number of policy interventions. A basic/fair knowledge of Java programming would be required.

Contact: Johan W. Joubert

Status: Project assigned to Ms Cherisé Surtees as a BPJ final year project in 2019.

049 Build a MATSim transit schedule from GTFS and *WhereIsMyTransport* API

Description: The public transit routes and schedules are often captured in the *General Transit Feed Specification* (GTFS) format, and this is then converted, through existing software infrastructure, into a transit schedule that is usable by the agent-based MATSim. But getting access to the GTFS feed is not always as simple. This project aims to program against the *WhereIsMyTransport Application Programming Interface* (API) and generate MATSim schedules directly. A fair knowledge of Java programming would be required. Some experience in MATSim is highly recommended.

Contact: Johan W. Joubert

Status: Available as BCS 780, or M.Eng project.

048 Evaluate HOV lane in City of Cape Town

Description: This project deals with implementing the High-Occupancy Vehicle (HOV) lane as it currently exists in the City of Cape Town on the N2, inbound, in the morning peak. That is, the lane reserved for public transport between Borcherds Quarry Rd and the M5. The goal of this project is to implement the HOV lane in MATSim and evaluate the effect it has on travel time. A basic/fair knowledge of Java programming would be required.

Contact: Johan W. Joubert

Status: Project assigned to Mr. Ruan Gräbe as a BPJ final year project in 2019.

047 Land use analyses from commercial vehicle movement

Description: The complex network research in our group means that we have a large data set of inter-firm connectivity. For each facility we have a coordinate, but mapping this to actual buildings is not always useful as commercial/freight vehicles perform their activities on the *periphery* of the building, and not inside the building itself. Instead, one needs to map the locations to the underlying erf/parcel. To this extent the City of Cape Town has a biannual Industrial Survey (last done in 2016) that is available on their *Open Data Portal*. This project entails mapping the facility locations to those industrial parcels, and perform the necessary (exploratory) analyses and research to identify patterns of connections.

Contact: Johan W. Joubert

Status: Available as BCS 780, M.Eng or PhD topic. Final scope to depend on the candidate's level.

046 Multi-objective oral examination scheduling and venue allocation at the University of Pretoria

Description: Every year the final years of the Department of Industrial and Systems Engineering at the University of Pretoria are required to present their projects at the final year oral examination. Due to the large number of final year students, the final year oral examination is usually scheduled over two to three days in three to four different presentation venues. Each final year student has an allocated supervisor, internal external examiner (from the department), and an external examiner from industry that must, amongst others, asses the student's project presentation.

At present, the final year oral examination is scheduled using a time consuming, and often inefficient, manual process. This manual scheduling of the oral examination is an extremely difficult task due to various restrictions, such as examiner, venue and student availability; and multiple conflicting objectives, such as time duration of the exam and convenience of examiners.

A multi-objective exam scheduling and venue allocation model is therefore required to assist with the final year oral exam scheduling process. Even though the exam scheduling problem has been widely studied in the literature, the use of multi-objective approaches to schedule exams and allocate them to different exam venues has not been extensively investigated in the literature.

This project focuses on developing a multi-objective oral exam scheduling and venue allocation model that can be used by the Department of Industrial Engineering to schedule final year project oral examinations.

Contact: Wilna L. Bean

Status: Completed by Abdullah Hassen in 2019.

045 Allocating cost and benefits during collaborative urban freight transportation

Description: Collaboration during urban freight transportation is a well known concept that is widely acknowledged as a potential way to improve logistics operations and reduce supply chain cost. An important consideration during collaboration, is how the various cooperating stakeholders, such as shippers, carriers and receivers, can share benefits emanating from the coalition. Game theory provides a framework to model interactions between different decisions-makers where their individual actions jointly determine the outcome the interaction and is often used to determine how costs should be allocated during collaborative transportation.

This project therefore focuses on using cooperative game theory concepts to develop a mathematical model that can be used to determine how benefits and costs emanating from a coalition can be fairly allocated between participating shippers, carriers and receivers during urban freight transportation.

Contact: Wilna L. Bean

Status: Assigned to MEng student Leonè Zevenbergen in 2020.

044 Embracing social media to improve supply chain competitiveness

Description: The social media revolution enabled anyone to share instantaneous messages to thousands of people in their social network, resulting in a rapid increase in the speed of gaining and sharing information globally. Consequently, many supply chains managed using traditional supply chain management techniques are struggling to keep up. Social media has already started to impact supply chains in various areas and the impact will likely increase exponentially in the future. Failure to respond to these developments may place supply chains at increased risk. It is therefore necessary for existing supply chains to adapt to these changing conditions and embrace social media as an opportunity to strengthen the supply chain and improve competitiveness. This project focuses on understanding the impact of social media on existing supply chains and propose ways for traditional supply chains to adapt and embrace social media to remain relevant and improve competitiveness.

Contact: Wilna L. Bean

Status: Completed by BCS student Athenkosi Jojo in 2018.

043 Evaluating the impact of congestion-based intermediate facility visit times on waste collection routes

Description: The routing algorithms developed by Willemse (2016) (see project 41) assumes that offloading times of waste collection vehicles are constant. This assumption is being formally tested in project 42. The objective of this project is to test what impact variable offloading times will have on waste vehicle routes, and if the offloading time is dependant on the number of vehicles currently in the facility.

The following approach is recommended. First, an average offloading time will be used to generate collection routes using the algorithms of Willemse (2016). Thereafter, variable offloading times generated in project 42 will be imposed and the expected and the actual times to complete the routes will be compared. Critical will be to see if the routes are still completed within the available working hours. Thereafter, an agent based approach will be used whereby each vehicle is allowed a few simple rules to improve its route completion time. Such rules may include visiting a offload facility sooner or later in its route, to avoid facility congestion, while adhering to vehicle capacity constraints, and making additional visits if required. This can then be compared against a system based optimisation approach where fixed offloading time-windows are prescribed to vehicles. The results of the two approaches can then be compared.

This project depends on output from project 42.

Contact: Elias J. Willemse

Status: Not currently available.

042 Analysing landfill and transfer station throughput times

Description: Using the available GPS records of waste collection vehicles, the objective of this project is the analyse how long the vehicles spend offloading their waste at landfills and transfer stations. Factors that influence this time, such as the number of waste vehicles already in the facility, will also be analysed. The following hypothesis will be tested:

Waste collection vehicles tend to reach their capacity at the same time during the day. All the vehicles then head to landfills and intermediate facilities, causing the facilities to become congested as they have limited resources, such as weigh-bridges, to process the vehicles. This causes vehicle delays at the facilities.

A possible output of this project is the actual time, and distribution thereof, that vehicle's spend offloading waste, and the expected time that a vehicle will spend at a facility given the number of vehicles that are already in the facility.

Contact: Elias J. Willemse

Status: Assigned to M.Eng student Llewellyn Steyn (2018) as part of project 41.

041 Generating input data for waste collection routing algorithms using GPS records and open data sources

Description: Willemse (2016) develop routing algorithms capable of generating residential waste collection routes for a waste collection fleet. The algorithms require detailed input data, such as the waste to be collected in each street-segment, as well as the travel time through and service time of each street-segment. Such data is typically not readily available. The purpose of this project is to use the GPS records of a waste collection fleet, as well as open data sources on the road network on which the fleet travel, collection subareas, location of landfills and transfer stations, offload times of the vehicles, and a census-based synthetic population, to extract the required data for the routing algorithms.

References:

Willemse, E. J. (2016). *Heuristics for large-scale Capacitated Arc Routing Problems on mixed networks*. PhD thesis, University of Pretoria, Pretoria. Available online from `http://hdl.handle.net/2263/57510` (Last viewed on 2017-01-16)

Contact: Elias J. Willemse

Status: Assigned to M.Eng student Llewellyn Steyn (2018).

040 Identifying supply chain communities in metropolitan areas

Description: Supply chain management theory teaches us about a number of distinct supply chain topologies (e.g. hub-and-spoke networks) and the pros and cons of each. But how well do these neat topologies really represent what happens in practice? Applying complex network theory to commercial activity chain data, we can construct a network of supply chain interactions in three of South Africa's largest metropolitan areas. This project should test different community detection techniques in an attempt to identify common supply chain topologies. The outcome of the project is an index of frequent topologies and a census of their prevalence in the three metropolitan areas. A successful applicant should be comfortable with programming (preferably R, but Java or Python as well).

Contact: Nadia M. Viljoen

Status: Unassigned. Project available for BCS 780.

039 Network growth model using (meta)heuristics

Description: In network theory there are a number of algorithms that can be used to generate synthetic networks of different types: random networks, small-world networks, or scale-free networks. The R package `igraph` have a number of these algorithms implemented. However, they are quite inefficient for large (realistic) networks, especially if you want specific network characteristics like those where the node degree follows a power law. In this project the student will be exposed to network theory as an exciting field to study the connectivity between nodes (with a variety of applications). The focus of the project will be to develop a (meta)heuristic approach to build synthetic networks that conform to predefined network specifications. The successful applicant should be comfortable with programming (preferably R, but Java or Python as well).

Contact: Johan W. Joubert

Status: Project available to BPJ or BCS 780 project.

038 Using blockchain technology to for supply chain verification

Description: Blockchain technology has recently become famous thanks to the eruption of cryptocurrencies. This technology offers a secure way of maintaining distributed ledgers of transactions. The benefits and possible applications of this technology are far-reaching. One suggested application is using it to verify all the process-steps and contributing partners in a supply chain. Conceivably, by simply accessing the blockchain of your product, one could verify whether all the ingredients in your snack bar truly are organic; whether a dubious supplier had any inputs to the manufacturing of your prescription drugs; or whether the cocoa used in your chocolate bar really wasn't harvested by child slaves. But what is required to implement blockchain technology across supply chains? And how is this different to existing technologies used for the same purpose? This is an open-ended research project. The exact scope and research methodology depends on the student.

Contact: Nadia M. Viljoen

Status: Assigned to Thabang Sebata as BCS 780 project.

037 Optimisation algorithm for a cashier allocation algorithm in `R`'s `simmer` package

Description: A discrete-event simulation model has been built to simulate the checkout area of a major grocery retailer. The checkout area consists of a main checkout (22 tills), an express checkout (4 tills) and a kiosk checkout (4 tills). The model was built in `R` using the `simmer` package. Management has two conflicting objectives: to minimise the total cashier hours per month and also to minimise the customer penalty incurred due to increased waiting times and customers walking out of the store. Thus far the model has been used to test different cashier allocation scenarios designed by supervisors and operational managers. Now a customised algorithm is required to search the solution space more fully for a local/global optimum.

Contact: Nadia M. Viljoen

Status: Assigned as BPJ project to Chané Hoogenhout and BCS project to Kirsten Young

036 Multi-echelon inventory optimisation for humanitarian supply chains in Africa

Description: Logistics is an important part of any humanitarian relief operation and can mean the difference between success and failure. In the humanitarian relief context, logistics refers to the processes and systems involved in mobilising people, resources, knowledge and skills to provide aid to vulnerable people affected by disasters (van Wassenhove, 2006). An integral part of humanitarian relief operations is the provision of critical supplies to affected individuals and humanitarian aid workers. Since humanitarian organisations are not for profit organisations, they are often plagued by resource limitations, negatively impacting their ability to provide relief to those in need. One way for humanitarian relief organisations to reduce logistics cost and improve demand satisfaction is to effectively manage inventory levels throughout their supply chains. This project therefore focuses on applying multi-echelon inventory optimisation techniques to improve inventory management effectiveness and efficiency for humanitarian aid organisations operating in Africa.

Contact: Wilna L. Bean

Status: Completed by BCS student Darren de Beer in 2018.

035 Warehouse space-allocation optimisation for Springbok Superspar

Description: Springbok Superspar is a prominent retail node in the town of Springbok, Northern Cape. The store serves a catchment area with a radius greater than 100km. The business is family-owned and has grown from a small grocer to Superspar status over three decades. Initially the store only occupied a small section of a larger industrial building but as it grew it occupied adjacent sections. As a result of this gradual occupation of the original building, the warehouse has some interesting layout challenges. One example of such challenges is the fact that the warehouse is on two separate levels with a single lift and staircase connecting the two. Furthermore, space constraints and spikes in peak volumes have prevented the operational manager from cementing a space allocation regimen that works robustly during both peak and off-peak periods. Solutions to improve the operational management of the warehouse are required of which a space-allocation optimisation model is foremost.

Contact: Nadia M. Viljoen

Status: Assigned as BPJ project to Ughard de Clercq

034 Workout archiving and programme balancing tool for a CrossFit® affiliate

Description: CrossFit® is an international fitness regimen that prides itself in forging elite fitness[1] through "constantly varied functional movements performed at high intensity". Affiliate facilities around the world are called *boxes*. **Ballistix CrossFit Somerset West**[2] was founded in 2009 as the 3rd affiliate in South Africa and has grown from strength to strength since then.

Boxes have scheduled classes that are typically an hour long. During these classes coaches guide athletes in completing a warm-up, skill or technique building exercises and finally the Workout of the Day (WOD). Programming these hour long sessions is both an art and a science. A wide variety of movements must be covered from gymnastics to weightlifting, running to rowing and more. Athletes must also be challenged over a range of time domains including sprints, medium-paced workouts and endurance-style workouts. In addition to striking a balance between these elements, coaches must also keep in mind the specific needs of the athletes at their box and must avoid repetition like the plague.

At Ballistix the workouts are programmed on a weekly basis by one of the coaches. Programming is done manually in Microsoft Word and then uploaded to relevant online platforms (e.g. BoxChamp, Facebook, emailed to specific athletes). The weekly programme is born from the coaches' expert knowledge, experience and intimate understanding of their athletes. They frequently draw inspiration from the CrossFit® main site, previous competition WODs and their extensive archive of WODs. The programming process takes about 3 – 5 hours a week, depending on the severity of the coach's "programmer's block".

Fully automating the programming function is strongly discouraged as there are too many human variables that cannot at this stage be reduced to algorithms and code. However, it could be possible to develop a tool that can produce a "draft programme" each week that a coach can use as a starting point. This could potentially save a coach a few hours each week — time that could be better spent on training, coaching or other elements of the business.

Contact: Nadia M. Viljoen

Status: Assigned as BPJ project to Murray Smith

033 Database design and volunteer scheduling for a literacy programme

Description: A non-profit literacy programme called *Open a Book for a Child, Shine Literacy Chapter*[3] has been implemented at the Waterloo Primary School in KwaZulu-Natal since 2012. Learners in Gr. 2 & 3 that are regarded as "at risk" due to sub-standard English reading and writing ability are served by this programme. Adult volunteers spend individual contact time with each learner on a weekly basis. A number of activities take place during these weekly sessions to improve the learner's English literacy. The programme has shown very encouraging results over the past years. Currently the maximum capacity is for 70 volunteers and 100 learners. The programme runs close to capacity. Each volunteer commits to one to three sessions a week and, depending on the available volunteers, learners have one to two hours contact time per week.

The administrative data behind this programme (class lists, progress tracking etc.) are maintained manually in Excel spreadsheets. In addition, the periodic scheduling of volunteers is also a manual process that must take into account a number of constraints imposed by the school timetable. Project requirements include:

- Design, build and populate a database that encapsulates all of the administrative and volunteer scheduling data.
- Develop a volunteer scheduling algorithm that the client can use on a periodic basis.
- Develop a training manual for the use of the database and scheduling algorithm by the client.

Contact: Nadia M. Viljoen

Status: Assigned to Karicke Piek as BCS 780 project.

[1] https://www.crossfit.com/what-is-crossfit
[2] http://www.ballistixfitness.com/
[3] http://www.shineliteracy.org.za/

032 Estimating commercial vehicle activity density

Description: Sakai et al. (2018) build on Giuliano et al. (2015) and the authors estimated freight trip density based on, amongst other variables, distance to motorway, population and employment density, and income. What was noteworthy is that access to motorway is the most significant accessibility metric. Employment is also better than establishment as a predictor. The purpose of this project will be to do a rigorous spatial analysis using the activity chains and complex network of South African commercial vehicle activities, and develop a model to estimate activity density. Since spatial auto-correlation becomes an issue in these types of analysis—the effects of neighbouring areas affect freight traffic demand—it is recommended the candidate considers a spatial lag model. To this extent, the R package `spdep` should provide sufficient support (Bivand and Piras, 2015).

References:

Sakai, T., Beziat, A., Heitz, A., and Dablanc, L. (2018). Testing the "Freight Landscape" concept for paris. *Transportation Research Record*, 2672(9):216–228

Giuliano, G., Kang, S., and Yuan, Q. (2015). Using proxies to describe the metropolitan freight landscape. Final report Project Number 15-1C, MetroFreight Center of Excellence, USC Sol Price School of Public Policy, University of Southern California, Los Angeles, California

Bivand, R. and Piras, G. (2015). Comparing implementations of estimation methods for spatial econometrics. *Journal of Statistical Software*, 63(18):1–36

Contact: Johan W. Joubert

Status: Unassigned. Project is available to BCS780, MIT800, or M.Eng students.

031 Multi-venue hockey umpire assignment

Description: In the primary school field hockey league, assigning umpires to weekly matches is a time-consuming and tedious exercise. In this project the student should investigate the existing literature on applying Operations Research (specifically optimisation) to sport tournament assignments. A partial model has been formulated in the working paper of Joubert (2017). The model need to be extended to the stochastic case where no-shows and other uncertainties play into the assignment. Since the model will be used as a routine decision-making tool, the project should also include a basic user interface to capture venue information, umpire availability, and umpire scoring.

References:

Joubert, J. W. (2017). A case study of umpire assignment to multi-venue field hockey tournaments. Working paper 054, Optimisation Group, Department of Industrial and Systems Engineering, University of Pretoria

Contact: Johan W. Joubert

Status: Not available at this point anymore.

030 Location routing problem using circuity factors

Description: The Location Routing Problem (LRP) is a well-researched topic in the Operations Research optimisation field (Drexl and Schneider, 2015). In this project the student should look into using empirical circuity factors to estimate the network distance between locations. Circuity factor is the ratio of the network distance to the Euclidean distance. The stochastic formulation (and solving) of the problem will be the key focus. The paper of Giacomin and Levinson (2015) may be of interest regarding circuity.

References:

Drexl, M. and Schneider, M. (2015). A survey of variants and extensions of the Location-Routing Problem. *European Journal of Operational Research*, 241(2):283–308

Giacomin, D. J. and Levinson, D. M. (2015). Road network circuity in metropolitan areas. *Environment and Planning B: Urban Analystics and City Science*, 42(6):1040–1053

Contact: Johan W. Joubert

Status: Unassigned. Project available to BCS780, or M.Eng students.

029 Relationship between FMCG retailers and the logistics connectivity of retail centres

Description: Most of the retail activities in South Africa takes place in retail centres and the major Fast Moving Consumer Goods (FMCG) retail tenants (such as Pick n Pay, SPAR, Woolworths, etc.) usually account for a major portion of freight movements to those centres. This project therefore focuses on analysing the relationships (if any exist) between various major FMCG tenants in retail centres in South Africa and the logistics connectivity of those retail centres. The student will gain an understanding of complex network theory and identify suitable metrics to evaluate the logistics connectivity of various retail centres. The logistics connectivity of these centres and the major FMCG retail tenants in those centres will then be analysed to understand the relationship between specific FMCG retail chains and the logistics connectivity of the centres they are located in.

Contact: Wilna L. Bean

Status: Investigation was completed by Mrs Kabelo Sekwadi for her BCS780 project in 2017.

028 Relationship between restaurants and the logistics connectivity of retail centres

Description: Many of the restaurants in South Africa are located in retail centres and restaurants account for the majority of freight movements to those centres. This project therefore focuses on analysing the relationships (if any exist) between various restaurant types situated in retail centres in South Africa and the logistics connectivity of those retail centres. The student will gain an understanding of complex network theory and identify suitable metrics to evaluate the logistics connectivity of various retail centres. The logistics connectivity of these centres and the different restaurants in those centres will then be analysed to understand the relationship between specific restaurant types (such as Coffee shops, Breakfast restaurants, Buffet restaurants, etc.) and the logistics connectivity of the centres they are located in.

Contact: Wilna L. Bean

Status: Project withdrawn.

027 Ordering behaviour of logistics receivers in South Africa

Description: This project focuses on obtaining an in-depth understanding of the key decisions of freight *Receivers* in urban areas in South Africa that drive the order of goods from *Shippers*. The main mechanism to be used for the collection of primary data required in this project will be in the form of establishment surveys. The target group for the survey will be Fast Moving Consumer Goods retailers in South Africa and even though these surveys will be the primary data collection mechanisms, data could also be collected from secondary sources as required. The outcome of this project would be to understand and analyse the reordering behaviour of freight *Receivers* in urban areas in South Africa.

Contact: Wilna L. Bean

Status: Project withdrawn.

026 How deterministic is the density-based clustering algorithm?

Description: Over the past few years we have used our implementation of the DJ-Cluster algorithm of Zhou et al. (2004) with the understanding that, as the authors claimed, the algorithm is deterministic. Computational results, however, have suggested that this may not be the case. Especially when parallelising the clustering over different zones, the points to be clustered may appear in different sequences. In this project the candidate will be required to set up experiments and test the level of deterministic behaviour. The interested candidate should be comfortable with Java.

References:

Zhou, C., Frankowski, D., Ludford, P., Shekhar, S., and Terveen, L. (2004). Discovering personal gazetteers: An interactive clustering approach. In *GIS: Proceedings of the ACM International Symposium on Advances in Geographic Information Systems*, pages 266–273

Contact: Johan W. Joubert

Status: Project allocated to Hugh Williamson for BPJ 2020.

025 Accuracy of 'next place prediction'

Description: In Joubert and Meintjes (2016) we used a path-dependent complex network approach to build a synthetic population of commercial vehicles, each with its own activity chain, and validated the results. The network of connectivity that we used could be seen as a type of Markov, and Gambs et al. (2012) used a novel variant of the Mobility Markov Chain (MMC) to predict the next location in a person's trip. The nice bit of their contribution is the ability to quantify and express the accuracy for their prediction. In this project the candidate will be required to investigate a quantifiable measure, and apply/demonstrate it on the commercial vehicle activity chains. This work relates to working paper 040.

References:

Joubert, J. W. and Meintjes, S. (2016). Freight activity chain generation using complex networks of connectivity. In *The 9th International Conference on City Logistics*, volume 12 of *Transportation Research Procedia*, pages 425–435

Gambs, S., Killijian, M.-O., and Del Prado Cortez, M. N. (2012). Next place prediction using mobility Markov chains. In *Proceedings of the 1st Workshop on Measurement, Privacy, and Mobility, MPM'12*

Contact: Johan W. Joubert

Status: Completed by Petrus Jansen van Rensburg (BPJ) for 2018.

024 Impact of intermediate facilities on waste collection operations

Description: Based on preliminary results from Project 023 we found that waste vehicles spend most of their time traveling between service locations, dumpsites and depots, and very little time on actually collecting waste. This is partly due to the de-centralised locations of landfills. One way to improve the service utilisation of vehicles is to use centralised transfer stations. The purpose of this project is to identify and use location models to identify potential locations for transfer stations, and then evaluate the impact of the stations on waste vehicle operations.

Contact: Elias J. Willemse

Status: Unavailable. Preliminary results have been obtained by Mr Sabastian Ammon (2017) for BPJ420. Further work available for BCS780, MIT800, M.Eng or PhD students.

023 Identifying and analysing value-adding, essential non-value-adding and non-value adding vehicle activities using GPS-data

Description: Non-private vehicle fleets serve specific functions. The purpose of this project is identify how much of the fleets activities can be classified as value-adding (for instance picking up cargo), essential non-value-adding (transport to cargo to an end destination) and non-value-adding (waiting at the end destination). The purpose is to quantify how much time is spend by the resource on each activity. Information to be used are a basic understanding of the fleet's purpose and operations and then GPS traces.

Contact: Elias J. Willemse

Status: Unavailable. Preliminary results have been obtained and by Mrs Ezanne Engelbrecht (2017) for BPJ420. Further work available for BCS780, MIT800, M.Eng or PhD students.

022 Locations analysis for incident response vehicle

Description: As a follow up to Project 21, this project involves using the incident location data to develop models and algorithms to assist with resource planning of response vehicles, including their "waiting" location, number of vehicles required, shift-setups, etc.

Contact: Elias J. Willemse

Status: Project assigned to M.Eng candidate Mr HM Bogiages with project 21 (2018).

021 Natural Language Processing to identify road incident locations

Description: Road incidents data, specifically relating to vehicle road accidents, is used by cities and private companies to plan their vehicle response operations. This includes the number of vehicles required, and their waiting locations. Optimisation algorithms have been developed to deal with such decision problems that require as input the geographical location of incidents. Incident sources exist, but their locations are not geocoded, and represented by a human entered address or location. Optimisation algorithms require geocoded, thus quantified, addresses. This project required using Natural Language Processing (NLP) tools to analyse the human-entered data fields and link them with available street names that with coordinates. Initially the data sources will include twitter posts, to which NLP has to be applied to identify if a post represent an incident, and its location, and OSM data such as street names, their types and locations.

Contact: Elias J. Willemse

Status: Project assigned to M.Eng candidate Mr HM Bogiages with project 22 (2018).

020 Bayesian networks for activity chain generation

Description: In Sun and Erath (2015) the authors used Bayesian networks to successfully generate a synthetic population of agents from census data. This project will deal, depending on the level of the candidate, on duplicating the work within the South African context (Masters level), and extending the procedure to also synthesise activity chain generation (PhD level) from travel diary data.

References:

Sun, L. and Erath, A. (2015). A bayesian network approach for population synthesis. *Transportation Research Part C*, 61:49–62

Contact: Johan W. Joubert

Status: Unassigned. Project available to Masters, PhD or PostDoc. Final project scope will be determined by the level of the candidate.

019 Complex network modelling for Cape Town's aviation connectivity

Description: Building a complex network representation of international flights connecting Cape Town International Airport. Currently the level of connectivity is measured using a standard set of network metrics. The objective of this project will be to support decision-making about the effect that adding or removing flights (connections) will have on these network metrics. The candidate's mandate will be to answer the question: *"can a complex network approach assist in route development?"*

Contact: Nadia M. Viljoen

Status: Project completed by Kyle Robertson as final year design project (BPJ) in 2017.

018 Append GPS traces with elevation data

Description: This research builds on the work with *Digicore* on estimating the risk associated with driver behaviour. The high resolution GPS traces only provide accurate positioning in the xy-plane. This project will follow a similar approach to Wood et al. (2014) to augment the GPS data with elevation data. Similar to project 012 elevation data from the *Shuttle Radar Topography Mission* (SRTM) will be used.

References:

Wood, E., Burton, E., Duran, A., and Gonder, J. (2014). Appending high-resolution elevation data to GPS speed traces for vehicle energy modeling and simulation. Technical Report NREL/TP-5400-61109, National Renewable Energy Laboratory

Contact: Johan W. Joubert

Status: Project assigned to BCS 780 and M.Eng student Jeanne-Marie Hugo for 2019–2020.

017 Anonymise trip data sets.

Description: The activity chains used in Joubert and Axhausen (2013), amongst other publications, are based on detailed vehicle movements that contain specific facility locations. In this project the objective is to aggregate the facilities to zonal level, and then use the aggregated activity chain descriptions to construct a directed network and generate a synthetic population from it (similar to Joubert and Meintjes (2016)). After providing some basic network statistics of the resulting graph, the candidate will be required to compare the activity chain characteristics with the original approach as published by Joubert and Meintjes (2016). Metrics will include the chain distance, geographic spread, and number of activities per chain.

References:

Joubert, J. W. and Axhausen, K. W. (2013). A complex network approach to understand commercial vehicle movement. *Transportation*, 40(3):729–750

Joubert, J. W. and Meintjes, S. (2016). Freight activity chain generation using complex networks of connectivity. In *The 9th International Conference on City Logistics*, volume 12 of *Transportation Research Procedia*, pages 425–435

Contact: Johan W. Joubert

Status: Unassigned. Project available to M.Eng students.

016 Considering the effect of different representations when building complex inter-firm networks

Description: In the work of Joubert and Axhausen (2013) we used a direct trip of a commercial vehicle between two facilities as a proxy that there is some *relation* between the two firms. Kurant and Thiran (2006) would refer to this as a *space-of-stops* representation. In this project, the candidate will have to consider an alternative representation, *space-of-changes*, where two firms, A and B, are considered connected if A simply *precedes* B in the activity chain. Consequently, how will the complex network characteristics differ between the two representations, and what are the (business) implications, especially in generating synthetic populations of commercial vehicles (Joubert and Meintjes, 2016)?

References:

Joubert, J. W. and Axhausen, K. W. (2013). A complex network approach to understand commercial vehicle movement. *Transportation*, 40(3):729–750

Joubert, J. W. and Meintjes, S. (2016). Freight activity chain generation using complex networks of connectivity. In *The 9th International Conference on City Logistics*, volume 12 of *Transportation Research Procedia*, pages 425–435

Kurant, M. and Thiran, P. (2006). Extraction and analysis of traffic and topologies of transportation networks. *Physical Review E*, 74(3):036114

Contact: Johan W. Joubert

Status: Project assigned to M.Eng candidate Mr Zane van Laar (2017).

015 Evaluate routing implications when using a 3D road network

Description: From Tavares et al. (2009) we know that a fuel saving of 12% can be achieved when considering a 3D road network. Building on project 012, this project entails a more concrete evaluation of a number of applications to see what effect a 3D network might have. The application area is currently not specified but may include waste collection vehicles (City of Cape Town).

References:

Tavares, G., Zsigraiova, Z., Semiao, V., and Carvalho, M. G. (2009). Optimisation of MSW collection routes for minimum fuel consumption using 3D GIS modelling. *Waste Management*, 29(3):1176–1185

Contact: Johan W. Joubert

Status: Unassigned. Available to BCS780 or M.Eng students.

014 An efficient algorithm for optimising a TSP with Time Windows

Description: In existing research where we model freight activity chains in MATSim, there is an opportunity to relocate a facility to a new location. One implication is that those activity chains

that do service the affected facility, will have to be locally optimised. This project solves a variation of the Travelling Salesperson Problem with Time Windows (TSPTW) with the additional benefit of using time-dependent travel time (from the MATSim model).

Contact: Johan W. Joubert

Status: This project was solved in-house. A greedy insertion heuristic was implemented within the MATSim framework to handle the relocation of facilities in commercial vehicle activity chains for the City of Cape Town project.

013 Labour fatigue constraints to Capacitated Arc Routing

Description: Much of our optimisation tries to improve the efficiency of routes. One concrete example is the collection of residential waste, where crews manually collect trolley bins and/or bags and load them into the collection vehicle. Current constraints consider route length and time restrictions, but not the impact of labour fatigue. That is, the more efficient the route, the harder the labourers will have to work. This makes it different to the VRP, for example, as the VRP deals with servicing a point. Once serviced, there is a rest period as the vehicle moves to the next demand point. In arc routing problems, however, the more efficient you are (servicing links consecutively), the harder the labourers are working. This is only good to a point, after which your efficiency goes down as either a) the unions give you trouble, or b) the workers' productivity goes down.

Contact: Elias J. Willemse

Status: Unavailable. A preliminary investigation was completed by Leonidas Petro for his final year project in 2016. Results were promising and publishable. Actual data is required to further test the concept.

012 Generating a 3D road network

Description: Using two critical data sources, namely *OpenStreetMap* and the public domain *Shuttle Radar Topography Mission* (SRTM) data set, generate a MATSim road network that includes an elevation field. Since each link is directional, each should have an *incline* field. The resulting network has significant implications in, for example, vehicle routing where the road gradient influences travel speed and accessibility.

Contact: Johan W. Joubert

Status: Solved in-house. MATSim now caters for 3D nodes, and daily 3D networks are generated from *OpenStreetMap* data for the major South African metros.

011 Evaluating waste collection beat crews

Description: Use Data Envelopment Analyses (DEA) to evaluate the different crews responsible for waste collection beats. Each decision-making unit (DMU) is a beat crew with specific inputs like truck type (rotary press versus paddle compactor), crew size, housing density and bin type (trolley versus bag).

Contact: Elias J. Willemse

Status: Unavailable. Following from discussion with City of Cape Town.

010 Waste generation modelling

Description: The City of Cape Town has made the GPS traces of their waste collection vehicles available. From project 009 we will know which links are serviced during a waste collection vehicle's route, and which are dead headed. This project aims to combine a synthetic population of households, the waste collection routes, and for example weighbridge data to estimate the amount of waste generated per household/individual.

Note: This project depends on the availability of data of actual waste quantities such as landfill weighbridge data, which is currently being sourced through the City of Cape Town.

Contact: Elias J. Willemse

Status: Unavailable. Preliminary results have been obtained in-house and by Llewelyn Steyn as part of his final year project in 2016.

009 Estimate service versus dead heading for waste collection routes

Description: Once map matching is done on waste collection vehicles' GPS traces, estimate the link speeds, and derive whether a vehicle serviced the link, or merely traversed it without servicing it. This project requires that the map matching project (001) or a separate implementation.

Contact: Elias J. Willemse

Status: Unavailable. Assigned to M.Eng student Llewellyn Steyn (2018) as part of project 41.

008 Route choice analyses between facilities

Description: Once we know what (actual) network routes commercial vehicles take between facilities, estimate how commercial vehicles make their route choices. This project will use existing activity chain data, and evaluate the route choice between sequential activity pairs. This project requires that the map matching project (001) and route retainment (002) be completed.

Contact: Johan W. Joubert

Status: Project available to BPJ410/420 or BCS780.

007 Dynamic waste VRP in MATSim

Description: One of the MATSim contributions, `dvrp`, deals with Dynamic Vehicle Routing Problems (DVRPs). During the mobility simulation service calls may be received, to which vehicles are dispatched. This project aims to model the dynamic service calls of commercial waste collection, and how the local municipality (or its service provider) responds and services those calls.

Contact: Elias J Willemse

Status: Unassigned. Project available to BPJ410/420, BCS780, MIT800, M.Eng or PhD students.

006 Evaluate reliability of Jsprit cost function with simulated MATSim score

Description: Jsprit solves an instance of the VRP variant, minimising cost for example, and inject agents into the MATSim simulator. This project aims to evaluate how close that JSprit score is to the actual experienced score amidst the congestion which, in turn, is a function of all the other agents' behaviour in the simulation run.

Contact: Johan W. Joubert

Status: Not allocated yet. Available to BCS780 or M.Eng student.

005 Point services in waste collection

Description: Residential waste collection accounts for the majority of the service delivery for local municipalities. Such problems are adequately described as Capacitated Arc Routing Problems (CARPs) and its variants. There is another component of waste collection that is point-based, such as roll-on-roll-off and commercial waste collection. These are better addressed using the Vehicle Routing Problem (VRP) and its variants. This project aims to identify appropriate VRP variants for such problems, and evaluate solving them using existing libraries such as Jsprit and OptaPlanner. A preliminary investigation was completed by Mr James Maden for his final year project in 2016. Results were promising but actual problem-instances are required to further test the concept. Such instances can be generated out of an available waste collection vehicle fleet dataset.

Contact: Elias J. Willemse

Status: Unavailable. A preliminary investigation was completed by Mr James Maden for his final year project in 2016. Results were promising but actual problem-instances are required to further test the concept.

004 Activity chain similarity.

Description: The Digicore data we work with provide a very large data set of activity chains that we've extracted from raw GPS records. In this project the objective is to study the *similarity* of those activity chains. Two perspectives: firstly the similarity of chains for a specific vehicle; and secondly the similarity among vehicles. A possible third aspect can consider similarity clusters

based on activity chains *only*, and then classifying vehicles based on the spread across the clusters they serve/execute.

Contact: Johan W. Joubert

Status: Currently this is Working Paper 038 of the Optimisation Group, Centre for Transport Development, Department of Industrial and Systems Engineering. Available to M.Eng student.

003 The influence of fuel/truck stops in activity chain distances.

Description: It has popped up in both Joubert and Axhausen (2013) and Sumarie's M-dissertation that fuel and truck stops are quite central actors. The questions this project aims to answer is how the trip's distance is influenced by also including the fuel stops. For example, say there is an activity sequence $A \rightarrow B \rightarrow C$, and B is a fuel stop. What is the additional distance incurred to visit B?

References:

Joubert, J. W. and Axhausen, K. W. (2013). A complex network approach to understand commercial vehicle movement. *Transportation*, 40(3):729–750

Contact: Johan W. Joubert

Status: Completed by Mr Zane van Laar for the module BCS 780 (Novel Industrial and Systems Engineering) during 2016. Write-up to follow.

002 Retaining route information in activity chains.

Description: In earlier research by Joubert and Axhausen (2011) we documented how to extract activity chains from GPS traces. The result, however, only retained the sequence of activities. The purpose of this project will be to also keep track of the routes traveled between the activities. The first step would be to just retain the GPS records, and subsequent work may map the GPS records to the actual road network (see project 001).

References:

Joubert, J. W. and Axhausen, K. W. (2011). Inferring commercial vehicle activities in Gauteng, South Africa. *Journal of Transport Geography*, 19(1):115–124

Contact: Johan W. Joubert

Status: Solved in-house

001 Map matching of GPS records to MATSim network.

Description: Develop an algorithm (in Java) that takes GPS records and matches them to a given road network. The network will be of the `xml.gz` type used in the Multi-Agent Transport Simulation (MATSim) toolkit which, in turn, is generated typically from *OpenStreetMap*. See the Extensible Markup Language (XML) document type definition (dtd) for MATSim networks here. The algorithm should report the most likely route, as well metric(s) reporting the goodness of fit. Consider the *GraphHopper* implementation in Java. *GraphHopper* is licensed under Apache 2.0, which is compatible with Gnu Public License (GPL) 3.0. The (estimated) entry and exit times for each link should be recorded so that link travel speed can be estimated.

Contact: Johan W. Joubert

Status: M.Eng: Mr Jaco-Ben Vosloo (2015–8).