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Intelligent waste management

Dr Günther Ruhe discusses his latest work in customising waste and recycling business knowledge to support the larger integrated Canadian waste management system

Could you describe the principal objectives of your current research project?

This particular project is devoted to providing a business intelligence solution inspired by the City of Calgary for the planning of waste and recycling services (WRS). The key business goals of the project are: to increase collection efficiency (in terms of vehicles, people and budget); provide transparency and trustworthiness of decisions made; develop the ability to proactively perform 'what-if analysis' to support strategic decisions related to personnel as well as fleet size and fleet type; and facilitate future quantitative and qualitative extension of recycling services. In regards to the technical side of the project, we are focused on the design, methodology development, implementation and validation of a WRS decision support system prototype solution.

What kind of technical components are you aiming to build? Have you had any success to date?

We aim to mine data repositories for business performance analysis, to reuse-orientated system modelling and simulation for strategic planning of WRS and facilitate transparency and trustworthiness in trade-off decision making. A survey has been used as a starting point for developing a specific prototype model for the City of Calgary to support the evolution of the existing processes. The simulation model targets the analysis of long-term effects of WRS management processes devised in the context of the City of Calgary's '80/20 by 2020 Strategy' – a commitment to an 80 per cent diversion of residential waste from City landfills by 2020.

So far, 20 staff members have independently evaluated a first version of a DSS prototype. The participants were asked to perform specific use cases, using the prototype, regarding decision making at both strategic and operational levels. At the strategic level, they were asked to evaluate the strategies regarding cost and quality of the services while, at the operational level, they analysed collection area designs in terms of total length of the collection routes. Results showed that the participants found the tool supportive and relevant to their daily tasks.

In what way has service management evolved in the past few decades?

Decades ago, waste management was about rubbish only. Now it is about a larger integrated waste management system. This system includes diverse services of collection and processing, such as rubbish, diverted materials and recycling, as well as major infrastructure components which include landfills, compost facilities and material recovery facilities.

How do you envisage the project progressing in the future?

We are currently in the process of extending this work for an additional year. This will give us the opportunity to enhance the project results targeted so far. For example, we have been investigating the effect of assigning different types of waste collection trucks to different collection areas and different operations. Our proposed solution will be designed to allow customisation to other municipalities. The benefits will be timely decisions with higher quality and increased transparency. In addition, decisions will be better justified and explained, resulting in a more comprehensive buy-in from all of the stakeholders involved.

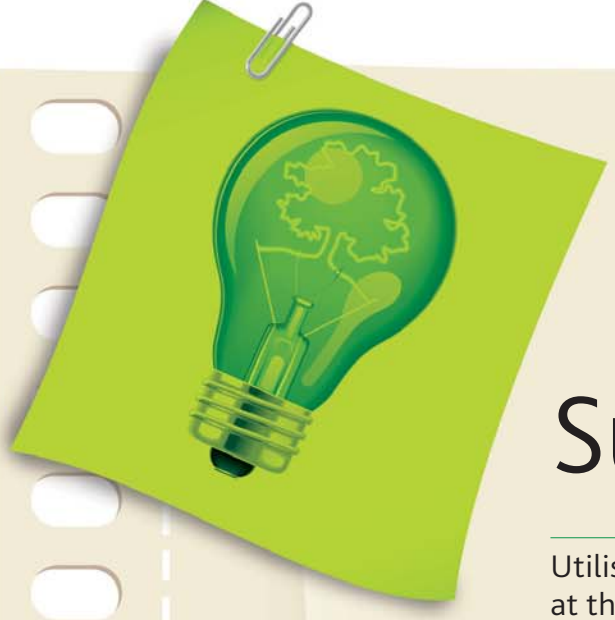
Our goal now is to come up with a general answer to the 3D personnel assignment problem and then develop a problem-specific search-based resolution in the context of waste and recycling services. This work is planned to be integrated as additional business use case for the existing Decision Support System.

Which areas of the waste management system still need refinement? How do you intend to investigate these avenues?

The work carried out in the first two System Dynamics simulation model prototypes will be enhanced by running proactive scenarios looking at factors impacting the collection service portfolio. We plan to integrate this research as an additional business use case for the existing Decision Support System, including a graphic user interface (GUI) allowing for the definition and execution of different scenarios within the system.

We will also study vehicle routing where the existing algorithms need to be revisited to consider additional constraints (like traffic or weather conditions). The results will have to take into account the different types of streets and pickup conditions (on both sides versus just one side of the street). Then the outcomes from the route planning can be visualised on GPS device displays of the truck operators to allow them to follow the recommended paths.

Finally, the current WRS Decision Support System will be enhanced by two additional business use cases we are planning. The results related to vehicle routing business use case are expected to be better applicable as additional constraints are taken into account. The user interface of the system will be improved to make it easier to use and understand. The knowledge and project base used to run different scenarios will also be enhanced.



Sustainable systems

Utilising computation to improve recycling efficiency, researchers at the **University of Calgary**, Canada, have developed a business intelligence solution which is being implemented across the city

THERE IS INCREASING demand for local authorities to manage residential waste more efficiently and effectively. Service providers are under ever-increasing pressure to deliver quality waste management services within budget and on time, all within the context of rapidly developing technologies, sustainable management goals and growing populations. This can present considerable challenges. One location where the local council has joined forces with the research community to tackle this mounting problem is Calgary in Canada.

The City of Calgary business unit for Waste & Recycling Services (WRS) manages residential waste collection for more than 300,000 residential homes. The unit operates three landfills and a number of community recycling depots. With a goal to recycle 80 per cent of the City's waste by 2020, the unit is implementing a citywide residential recycling service. In addition, they require cutting-edge business systems to enable effective decision making and cost reduction. The novel business intelligence is being developed under the auspices of a project which is part of The Urban Alliance; a research partnership between the City of Calgary and the University of Calgary, and led by the University of Calgary's Software Engineering Decision Support Laboratory.

USING BOTH STRATEGIC AND TACTICAL APPROACHES

Business Intelligence technologies look into historical, current and predictive aspects of business operations with the aim of supporting improved decision making. The focus of this project is to deliver just this for the planning of waste and recycling services. Dr Günther Ruhe, Principal Investigator and Professor at the University of Calgary, explains that their work is driven by the fact that traditional and strategic planning methods are no longer sufficient to manage the complexity of services required and the scale at which they are needed: "Decision making towards waste services needs to be more effective and efficient in order to accommodate resource and budget constraints of the forthcoming years, and this is where this project will play a significant role," he outlines.

At the strategic level, the Bayesian belief network (BBN) is being employed to assist the team in constructing a conceptual model describing the causal effect between the variables of the system. BBN allows for sensitivity analysis to find the variables with highest impact on cost and quality of services; forward propagation to evaluate user scenarios and rank the possible scenarios based on their impact on cost and quality of service; and backward propagation to discover the scenarios that lead to the desired state of service. Intelligent survey functionality offered by the 'Very Best Choice' platform was also used to elicit and prioritise the system variables using domain experts' knowledge.

In terms of tactic, the strategic decisions of the previous level are realised and then implemented. "We have considered two main components at this level: learning and optimisation," observes Ruhe. "The learning aspect aims to predict the values of the input variables (of the BBN model) while the optimisation module produces efficiency based on the results of the BBN analysis." Both levels access a data warehouse to enable adjustment and verification, and visualisation helps the operator to undertake further assessment. Decision support is another vertical concept which is applied to strategic and tactical components which, due to bi-layer interaction, leads to a nice transparency of the strategic decisions.

MODELLING AND SCENARIO BUILDING

The University of Calgary's lab has created a causal model for strategic planning using BBN which supports users implementing decision analysis, the result of which is a trade-off model for the desired output (leaf) variables. The sensitivity analysis creates a ranking of the root (and internal) variables based on their impact on the leaf variables, while the backward analysis suggests the distributions of the root variables in

INTELLIGENCE

A BUSINESS INTELLIGENCE SOLUTION FOR PLANNING OF WASTE AND RECYCLING SERVICES

OBJECTIVES

- Mining of data repositories for business performance analysis
- Reuse-orientated system modelling and simulation for strategic planning of WRS
- Transparency and trustworthiness of trade-off decision making
- WRS decision support prototype development
- Empirical evaluation of the prototype and its impact on transparency and trustworthiness of decision making

KEY COLLABORATORS

Emad Livani; **Arash Niknafs**; **Abbas Hosseini**; **Elham Paikari**; **Dr Jörg Denzinger**, University of Calgary

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order to create the desired output. It took the project alliance several meetings and hours of discussion with domain experts from WRS to formulate the final market-ready BBN model. Additional variables, variable distributions and probability tables have since been introduced.

Following its completion, a number of scenarios have been evaluated by changing the variables one at a time to assess the likely outcome. One example exists whereby the Lab evaluated the impact of adding new truck parking locations in one of the many brownfields in the City of Calgary. Finding the optimum place for parking was addressed by looking into operational details. By inputting the existing location alternative or land required into the model, a list of the decision criteria (such as environmental impact or distance from landfill) could be generated implicitly or explicitly to evaluate alternatives to provide science- and evidence-based decision making.

PHD STUDENT ARASH NIKNAFS AS TRUCK CO-PILOT

A second example of where the model can deliver information for business decisions is in the forecasting of waste volume and waste profiles. Considering population and housing structures with regards to the three different districts in City of Calgary and its implications on fleet and manpower management, comprehensive census-based statistics were entered into the model. The result provided projected waste and recycle levels to be generated for each district over the next five years.

Pattern-based routing is another consideration which the model addresses. Existing patterns, characteristics of the beat and the day of recycling in addition to comparative evaluations of beat schedules, are entered into the model to glean optimal service guidelines; providing the driver with recommendations for the best route. The patterns reflect previously successful management strategies which are determined using running optimisation algorithms.

A TAILORED APPROACH

Besides delivering a higher quality of both business and strategic decisions, the main benefit of this project is in increased transparency and the capacity to make more timely decisions. As such, the key innovation anticipated comes in the form of a unique methodological integration between data mining, modelling, simulation and optimisation to facilitate trustworthy decision processes in service planning; the benefit of which goes far beyond Calgary. Because of the values already realised from the WRS DSS solution, Ruhe now plans to make results available to partners of Waste and Recycling Services, such as The Calgary & Region Waste Reduction Partnership – a group of local waste management companies and provincial stakeholders in the waste management industry. "This research project," concludes Ruhe, "will directly affect the way that all or most of these partners deliver services to their customers." They envision reuse-orientated systems will be adopted by other Canadian municipalities and are ready to facilitate the transition to meet the ambitious targets of waste reduction across the country.

The project delivers increased transparency and the capacity to make more timely decisions

The project serves as a prototype of successful collaboration between industry and academia and would not have been possible without NSERC support. Initiated by the City of Calgary, it is based on a proper understanding of current and future needs and was discussed in several rounds of preparation meetings.

The City WRS department supported the initial phase and throughout the project there was a stimulating and always constructive atmosphere. Annual workshops were held with 20 key participants and stakeholders and one graduate student even collected practical experience as becoming a truck co-pilot (**above**).

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