戦略的国際共同研究プログラム(SICORP)
日本－イスラエル共同研究
終了報告書　概要

1. 研究課題名：「観光客の流動パターンの把握と避難経路情報の提供： Tourists' Flow Patterns Identification and Information Provision for Safe Evacuation」
2. 研究期間：2018 年　6 月 1 日～　2022 年　3 月　31 日
3. 主な参加研究者名：

日本側チーム

	氏名	役職	所属	研究分担
研究代表者	シュマッカー ヤンディャク	准教授	京都大学大学院　工学研究科　都市社会工学専攻	研究コーディネート
主たる 共同研究者	宇野 伸宏	教授	京都大学大学院 工学研究科 社会基盤工学専攻	すべての活動を支援する
研究参加者	倉内 文孝	教授	岐阜大学土木工学専攻	WP1、WP3、WP4へのアドバイス
研究参加者	西田 純二	教授	株式会社　社会システム総合研究所	データ収集のサポート
研究参加者	中村 俊之	准教授	名古屋大学　未来社会創造機構	実験支援
研究期間中の全参加研究者数　5名				

相手側チーム

	氏名	役職	所属	研究分担
研究代表者	Yuval Hadas	Senior Lecturer	Bar-Ilan University	Research co-ordination
主たる 共同研究者	Boaz Ben-Moshe	Assoc. Professor	Ariel University	Software development
主たる 共同研究者	Oren Nahum	Senior Lecturer	Bar-Ilan University	Data analysis, support of experiments
研究期間中の全参加研究者数　3名				

4. 国際共同研究の概要

COVID 危機が発生するまでは、イスラエルや日本を含め、世界的に観光客が急増すると同時に、観光客の安全に対する懸念が高まっていた。これは、災害の頻発や深刻化に起因しており、テロリズムなど大勢の観光客が格好の標的となりかねない事態があるためである。さらに、観光客は情報が少ないため、災害発生時等には混乱した状況に陥りやすくなると考えられる。

よって、本研究課題では、観光客の滞在時間や経路選択などの「ミクロな意思決定」を理解することを通して観光客の流れや観光客が歩行ルートをどのように選択するかを推定する方法を探ることを目的とした。Wi-Fi を発信しているデバイスから信号を受信し、さまざまな場所にいる一部のユーザーを時間の経過とともに識別可能な Wi-Fi センサデータを有力なデータソースとして活用し、安価で簡単に設置できる Bluetooth タグの使用法を調

査することに加え、平常時と災害時の観光客の行動を分析し、災害時に観光客をより安全な場所に誘導する方法を探った。混雑が発生する可能性が高い場所に関する知識を基に、観光客の流れを適切に分散させるための情報を提供する方法を示した。

5. 国際共同研究の成果

5-1 国際共同研究の学術成果および実施内容

WP1 は文献を検討し、観光客に関するさまざまなデータ ソースを統合するためのフレームワーク開発を行った。都市部における観光客の位置と流れに関する情報を収集し、より効率的で安全な避難経路にこの情報を利用するための枠組みを提案した。
WP2 の目的は、WiFi センサーを使用して日本の観光ルート情報を収集することであり、実際に京都の先斗町エリアにセンサーを設置し、特に観光地である東山エリアからの一連の Wi-Fi センサー データを収集した。収集データの分析により季節や時間帯により変動があることが分かった。
WP3 では、Wi-Fi センサー データを分析して観光客の行動パターンを抽出することを目指した。東山 Wi-Fi データを使用して、選択モデル、特に「再帰的ロジット モデル」を構築し、Wi-Fi データと GPS トレースとのデータを統合することにより、観光客の歩行ルートを予測するモデルを構築することができた。
WP4 は、緊急時の観光ルートの理解に焦点を当てた。当初計画されていた実験の一部は、COVID の制限により実行できなかったため、360 度の写真と 3D メガネを使用したバーチャル リアリティ アプリケーションを開発し、突然の災害状況を想定した VR（仮想現実）実験を実施した。それにより VR ツールにより例えば道路幅や直進性などいくつかのルート選択時の決定特性を抽出できることを実証した。また、その結果を避難シナリオ シミュレーションに実装し、要所での経路案内の必要性を示した。
WP5 では、ローカルの Bluetooth センサーを使用して、観光客に役立つルート案内情報を提供できることを実証することを目指した。Bluetooth タグと「Nearbee」アプリを用いて東山エリアで実験を行い、センサーに近づくと、清水寺へのルートや地元のお店に関する情報を得ることができるなどセンサーが観光客のルート選択にある程度影響を与える可能性があることを実証した。但し、避難シナリオでの有用性を示すには、さらなる研究が必要である。

5-2 国際共同研究による相乗効果

国際共同研究を通じて、日本とイスラエルの観光客の行動パターンにおける共通の課題や両国が独自の表記体系を持つことを一因とした異なる課題があることが明らかとなった。観光客が狭い道路や混雑した地域を移動する日本とイスラエルの課題を反映した上で、観光客のルート選択を表現可能な数理モデルに関するアイデアとソリューションを開発した。さらに、プロジェクトチームの学際性により、ソフトウェア開発と交通計画を組み合わせることができた。また、国際共同研究における議論を通じて、VR ゲーム、Bluetooth センサデータと Wi-Fi センサデータのマッチング、Bluetooth データの観光客への通知等の実現が可能となった。

5-3 国際共同研究成果の波及効果と今後の展望

このプロジェクトは、いくつかの後続の研究活動に貢献し、両国の研究チームが継続的な研究のための資金を獲得するのに役立った。日本チームは、大学キャンパス内の混雑具合を計測するための Wi-fi センサーの設置について、資金を獲得した。また、研究テーマそのものを直接継続するのではなく、例えば WP3 で実施したデータ統合の実験を通して新たに

欧州 3 大学との共同研究が始まる等このプロジェクトで得た専門知識を応用した活動もある。また、イスラエルのチームとの VR アプリケーションとシミュレーションに関する研究は、このプロジェクトの終了後も継続され、センサー データの公共交通計画への利用も今後検討を進める予定である。

Strategic International Collaborative Research Program (SICORP)
Japan－Israel Joint Research Program
Executive Summary of Final Report

1. Project title： Tourists' Flow Patterns Identification and Information Provision for Safe Evacuation
2. Research period：2018/06 ～ 2022/03
3. Main participants：

Japan-side

	Name	Title	Affiliation	Role in the research project
PI	Jan-Dirk Schmöcker	Associate Professor	Kyoto University, Department of Urban Management	Research co-ordination
Co-PI	Nobuhiro Uno	Professor	Kyoto University, Department of Civil and Earth Resource Engineering	Supporting all activities
Co-PI	Fumitaka Kurauchi	Professor	Gifu University, Department of Civil Engineering	Advising WP1, WP3 and WP4
Collaborator	Junji Nishida	Professor	Japan Research Institute for Social Systems	Supporting the data collection
Collaborator	Toshiyuki Nakamura	Assoc. Professor	Nagoya University, Institute for Innovation for Future Society	Supporting experiments
Total number of participants throughout the research period: 5				

Partner-side

	Name	Title	Affiliation	Role in the research project
PI	Yuval Hadas	Senior Lecturer	Bar-Ilan University	Research co-ordination
Co-PI	Boaz Ben-Moshe	Assoc. Professor	Ariel University	Software development
Co-PI	Oren Nahum	Senior Lecturer	Bar-Ilan University	Data analysis, support of experiments
Total number of participants throughout the research period: 3				

4. Summary of the international joint research

Until the COVID crisis hit, tourist numbers have been increasing rapidly worldwide including Israel and Japan. At the same time, safety concerns of tourist are growing, this is due to increasingly frequent and severe natural hazards as well as terrorism, where large crowds of tourists can become easy targets. Furthermore, tourists are often less informed and are therefore more vulnerable to be trapped in chaotic situations.

With this background, our project therefore had had as one objective to explore methods and data as to how tourist flows and route choices can be estimated. In particular we aimed to understand “micro-decisions” of tourists such as how long they stay in places and their principles of route selections while walking. We used Wi-Fi sensor data as a promising new data source. The sensors can pick up signals from any Wi-Fi emitting devices and re-identify some users over time at different locations. In addition, the project explored the usage of Bluetooth tags as these are cheap and easily installed. Further, we analyzed tourist behavior during normal situations and during disasters and explored ways to guide tourists to safer locations in case of disasters. With the knowledge of where likely crowding will occur we showed how information can provide better distributed tourist streams. Using gamification, we aimed to show how crowding can be eased in normal situations, before a disaster occurs. An objective of the project was further to conduct case studies in touristic locations in the two countries. In Japan we selected Higashiyama, Kyoto, as our main target area. To achieve our goals the project team included transport planners, operation research experts as well as software developers.

5. Outcomes of the international joint research

5-1 Scientific outputs and implemented activities of the joint research

The project was split into five man workpackages (WPs) and each of these has led to results. WP1 reviewed the literature and developed a framework for integration of various data sources. Implementation: Through joined discussion and data collection we refined the original framework. Result: A discussion paper was published that discusses the data available and their limitations for tourist flow estimation. The revised framework shows how data collection with various technologies during normal touristic seasons can help planners to prepare for disasters. We discuss how this information can be used for more efficient and safe evacuation routing in line with the project objectives.

The goal of WP2 was to collect tourist route information in Japan with WiFi sensors. Implementation: We installed sensors in the Pontocho area of Kyoto as well as build on a set of sensor previously installed. The collaboration with this project provided us with a wider network of sensors and in particular with a set of Wi-Fi sensor data from the touristic Higashiyama area. Also Wi-Fi sensors were installed on the Bar-Ilan campus, in Tel Aviv Israel. The Israeli data collection was postponed due to COVID and is currently still ongoing. Results: A rich set of Wi-Fi sensor data was collected from Kyoto that could be used for further analysis. The aggregate analysis shows seasonal and time-of day variations of the busyness at the surveyed locations.

In WP3 we aimed to analyse the Wi-Fi sensor data to extract behavioural patterns of tourists. Implementation: We constructed choice models, in particular “recursive logit models” with the Higashiyama Wi-Fi data. We also conducted data fusion of the Wi-Fi data with other GPS traces of tourists. Results: We could build models that describe and predict tourist walking routes. We could show the impact of shops and attractions for decisions as to which route to take at junctions. More generally, we could demonstrate the value of Wi-Fi data for tourist flow estimation and prediction.

WP4 focused on understanding tourist routes during emergencies. Implementation: Since some of the originally planned experiments were not feasible due to COVID restrictions we developed a Virtual Reality application with 360-degree pictures and 3D glasses. An application was developed where respondents are virtually placed at junction and have to decide which route they would take that appears to lead to a safe evacuation location. Experiments were conducted with domestic tourists in the Higashiyama area of Kyoto. Results: We demonstrated that the VR tool can extract some decision characteristics. We quantified, for example, the importance of the road width and the preference for continuing going straight. We then implemented the results into an evacuation scenario simulation and showed the need for route guidance at key points.

The goal of WP5 was to demonstrate the usage of local Bluetooth sensors can provide

tourists with useful route guidance information. Implementation: We conducted an experiment in the Higashiyama area with Bluetooth tags and the “Nearbee” app. When close to a sensor, participants could obtain information about the routes to Kiyomizu temple as well as local shops. The sensors also functioned as a “stamp rally”. Results: We demonstrated that the sensors can to some degree influence the route choice of tourists. The stamp rally further raised the interest of tourists to explore nearby attractions. We discuss that further research is needed to show their usefulness during evacuation scenarios. Finally, with respect to the administrative and concluding WPs we note that we published and are still in the process of publishing some of the research results.

5-2 Synergistic effects of the joint research

The collaboration helped us to realise common and different challenges for tourists in Japan and Israel, partly due to both countries using unique writing systems. Through the collaborative research we developed ideas and solutions to represent and mathematical model tourist route choices that reflect challenges in both Japan and Israel where tourists navigate in areas with small, crowded roads. The interdisciplinarity of the project team further allowed us to combine software development and transportation planning. The VR game, matching of Bluetooth sensor data and Wi-Fi sensor data as well as usage of Bluetooth data for tourist notifications are developed as part of the joined discussions.

5-3 Scientific, industrial or societal impacts/effects of the outputs

The project has contributed to a range of follow-on research activities and helped the Japanese team to obtain funding for continued research. Firstly, the Kyoto team has obtained funding to install a set of Wi-Fi sensors on the university campus to measure crowding. Several researchers of the Japanese team are further in discussions for Wi-Fi sensor installations in Japan and abroad. The data analysis and experience from this project have been important for this. Secondly, two of the Japanese researchers are involved in a CONCERT project funded by JST with three European universities. The objective of that project is to use deep learning techniques to reveal some of the urban dynamics during the COVID dynamic and other disturbances. The data fusion experiments in WP3 of this project have inspired the proposal that led to this new project. Thirdly, the research has led to continued research between the Israeli and Japanese researchers. In ongoing work we are seeking to advance the VR tool and are seeking funding for related research directions. The two PIs have also been discussing collaboration with respect to using sensor data for public transport planning.

国際共同研究における主要な研究成果リスト

1. 論文発表等

Shen, K, Schmöcker, J.-D., Sun, W.Z. and Qureshi, A.G. (2022). **Calibration of sightseeing tour choices considering multiple decision criteria with diminishing reward.** Accepted for publication in Transportation. 10.1007/s11116-022-10296-7

Gao, Y. and Schmöcker, J.-D. (2022). **Distinguishing Different Types of City Tourists through Clustering and Recursive Logit Models applied to Wi-Fi data.** Asian Transport Studies, 8, 100044. https://doi.org/10.1016/j.eastsj.2021.100044

Sabashi, K., Ben-Moshe, B., Schmöcker, J.-D., Hadas, Y. and Nakao, S. (2022). **Understanding Tourists' wayfinding during evacuation based on a Virtual Reality approach.** Transportation Research Records, 62, 640-647.

Gao, Y. and Schmöcker, J.-D. (2021) **Estimation of Walking Patterns in a Touristic Area with Wi-Fi Packet Sensors**. Transportation Research Part C, 128, 103219. https://doi.org/10.1016/j.trc.2021.103219.

Wachtel, G., Schmöcker, J.-D., Hadas, Y., Gao, Y., Nahum, O.E. and Ben-Moshe, B. (2021). **Planning for Tourist Urban Evacuation Routes: A framework for improved data collection and evacuation process**. Environment and Planning B: Urban Analytics and City Science, 48(5), 1108-1125. https://doi.org/10.1177/2399808321994575

Schmöcker, J.D. (2020). **Estimation of city tourism flows: challenges, new data and COVID**. Transport Reviews. 41(2), 137-140.

Gao, Y. and Schmöcker, J.-D. (2021). **Modelling sequential ticket booking choices during Chinese New Year**. Transportation, 48(4), 1987-2010. https://doi.org/10.1007/s11116-020-10118-8.

Ko, T., Qureshi, A.G., Schmöcker, J.-D. and Fujii, S. (2019). **Tourist Trip Design Problem considering Fatigue**. Journal of the Eastern Asia Society for Transportation Studies. Vol 13, 1233-1248.

2. 学会発表

Nakao, S. and Schmöcker, J.-D. (2022). **Improving Tourist Area Awareness using Bluetooth Beacons and Gamification**. 101st Annual Meeting of the Transportation Research Board. Washington D.C., U.S. (held online).

Hadas, Y., Ben-Moshe, B., Wachtel, G., Nahum, O., Schmöcker, J.-D., Sabashi, K. and Gao, Y. (2021). **Assessing the navigation error characteristics of residents and tourists during evacuation – a combined simulation and virtual reality approach**. Accepted after peer-review for 8th International Conference on Transport Network Reliability (Stockholm, 24-26 June).

Kobayashi, H., Zhang, C., Schmöcker, J.-D., Nakao, S. and Yamada, T. (2021). **Markovian Analysis of tourist tours based on Travel App Data from Kyoto, Japan.** Online Presented at 25th International Conference of the Hong Kong Society for Transportation Studies (HKSTS), December 12-14.

Gao, Y. and Schmöcker, J.-D. (2021). **Distinguishing Different Types of City Tourists through Clustering and Recursive Logit Models applied to Wi-Fi data.** Presented at the 14th International Conference of Eastern Asia Society for Transportation Studies (EASTS). September 12-15, Hiroshima, Japan. (Held online).

Kobayashi, H., Zhang, C., Schmöcker, J.-D., Nakao, S. and Yamada, T. (2021). **Markovian Analysis of tourist tours based on Travel App Data from Kyoto, Japan.** Online Presented at 25th International Conference of the Hong Kong Society for Transportation Studies (HKSTS), December 12-14.

Sabashi, K., Schmöcker, J.-D., Nakao, S. Ben-Moshe, B., and Yamada, T. (2021). **細街路を含む観光地における避難誘導に関するシミュレーション研究.** 第 63 土木計画学研究発表会・春大会・オンライン

Sabashi, K., Ben-Moshe, B., Schmöcker, J.-D., Hadas, Y. and Nakao, S. (2021). **Understanding Tourists' wayfinding during evacuation based on a Virtual Reality approach.** 24th EURO Working Group on Transportation Meeting, EWGT 2021, 8-10 September, Aveiro, Portugal

Shen, K, Schmöcker, J.-D. and Qureshi, A.G. (2021). **Sightseeing tour choices considering multiple satisfaction criteria: Case study with Kyoto survey data.** Presented at the 100th Annual Meeting of the Transportation Research Board. Washington D.C., U.S. (held online).

Wachtel, G., Schmöcker, J.-D., Gao, Y., Nahum, O.E. and Hadas, Y. (2020). **Planning for City Tourist Evacuation Routes: Collecting and Providing Information.** 99th Annual Meeting of the Transportation Research Board. Washington D.C., U.S., January 13-16. Peer-reviewed full paper.

Wachtel, G., Schmöcker, J.-D., Hadas, Y.,Gao, Y., Nahum, O. and Ben-Moshe, B. (2020). **Planning for Tourist Urban Evacuation Routes: Collecting and Providing Information.** ADBI-Purdue University-University of Tokyo Virtual Workshop on Resilience of Cities to External Shocks: Analysis, Modeling, and Economic Impacts. 27-28 October 2020, ADBI, Tokyo

Shen, K., Schmöcker, J.-D., Gao, Y. and Qureshi, A. (2019). **Estimation of city tourism tours with survey data from Kyoto.** 9th Int. Symposium on Travel Demand Management, Edinburgh, U.K., June 19-21.

Gao, Y. and Schmöcker, J.-D. (2019). **Tourist Route Choices and Short-Term Flow Predictions in Tourist Areas Based on Wi-fi Packet Data.** 60th Japan Infrastructure Planning Conference (Autumn Meeting), Toyama, Japan. Nov. 30 – Dec. 2.

Gao, Y. and Schmöcker, J.-D. (2019). **Tourist Route Choices and Short-Term Flow Predictions in Tourist Areas.** International Choice Modelling Conference (ICMC2019), Kobe, Japan, Aug 19-21.

Sun, W. and Schmöcker, J.-D. (2018). **A Method To Classify Bus Bunching Events Using AVL Data.** 98th Annual Meeting of the Transportation Research Board. Washington D.C., U.S; January 13-17, 2019. (Peer-reviewed full paper)

3. 主催したワークショップ・セミナー・シンポジウム等の開催

International Workshop on Transport Network Analysis under Emergency Situations. Japan, Gifu, Heartful Square Gifu, Daikenshushitsu. 2nd October 2018. 40 Participants. Organisers: Jan-Dirk Schmöcker and Fumitaka Kurauchi.

ICT for Resilient Society workshop: Evacuation planning and operations. Israel, Tel Aviv, Beck auditorium, building 410, Bar-Ilan Campus. 7th March 2019. 20 Participants. Organiser: Yuval Hadas.

Project closing workshop. ICT for Resilient Society workshop: Evacuation planning and operations. (2) Israel, Tel Aviv, Building 507, Room 105, Bar-Ilan Campus. 6th November 2022. 10 Participants. Organiser: Yuval Hadas. From the Japanese team Jan-Dirk Schmöcker participated.

Other workshops cancelled due to COVID.

4. 研究交流の実績（主要な実績）

Project meeting in Kyoto, 3 October, 2018. All Japanese and Israeli project members participated.

Project meeting in Tel Aviv, Israel, 5 and 6 March, 2019. Most Japanese and Israeli project members participated. Following the project meeting a student of Kyoto University (Mr Yuhan Gao) stayed at Bar Ilan until 16 March for research exchange.

Mr Guy Wachtel of Bar-Ilan University visited Kyoto for two weeks for joined research activities, 15-31 July, 2019.

Second visit to Israel by members of the Japanese team, 20-24 September 2019.

Follow-up project meeting in Kyoto, 15 October, 2022 with five Israeli project members.

5. 特許出願

None

6. 受賞・新聞報道等

The presentation by Wachtel et al (2020). Planning for Tourist Urban Evacuation Routes: Collecting and Providing Information. ADBI-Purdue University-University of Tokyo Virtual Workshop on Resilience of Cities to External Shocks: Analysis, Modeling, and Economic Impacts. 27-28 October 2020, ADBI, Tokyo was rewarded a financial reimbursement.

7. その他

None