International Dual Master Degrees Program in Smart Cities

Ruey Long Cheu[1], Tomas Horak[2], Carlos Ferregut[3], Miroslav Svitek[4], Michal Postranecky[5]

Abstract— In January 2018, Czech Technical University in Prague (CTU) and The University of Texas at El Paso (UTEP), signed a Memorandum of Understanding (MOU) to jointly develop and implement a Dual Master Degrees program in Smart Cities. Since then, the program structure has been decided, and the management team hopes to start the program with the first cohort of students in August 2018. In this paper, the authors, who are the key leaders in the development of this program, share the history, program structure, enabling teaching facilities, and challenges with the readers.

Index Terms — **Smart Cities, international collaboration, living laboratory, education, quality of life.**

I. BACKGROUND

T he smart cities concept uses modern technologies to generate synergy between various subsystems (transportation, logistics, safety and security, energy, buildings, administration, etc.) in a city to improve quality of life of its residents.

The smart cities solutions strive for effective coordination of some, if not all of the city's subsystems, taking into account the common desire of sustainable development of society while improving the quality of life of city residents. This can be achieved by coordinated efforts to minimize the resources used (water, gas, electricity, land use), while at the same time maximizing the efficiency of the existing infrastructure (transportation, energy and telecommunication networks, information centers, etc.). As a result, the city is able to deliver better services and the residents can enjoy better quality of life.

It is possible to apply the smart cities concept towards defined goals or generic targets. The defined goals may be optimization of energy consumption, improvement of air quality, reduction of noise, regulation of transportation systems, etc. Alternatively, the generic targets support the identity of a given place and urban structure, i.e. its own historic, cultural, ecologic or aesthetic essence. The smart cities concept can be also applied in a different scope or context, e.g. smart town, smart village or smart region.

Because smart cities solutions require professionals in different disciplines (such as engineering, computer science, business, psychology, communications, etc.) to work as a team, engaging residents in the process, education of the smart cities decision makers, solution developers and other stakeholders needs a different approach. The authors believe that the undergraduate curriculum should deliver the fundamental knowledge to students in the respective academic disciplines; while the graduate program shall bring exposure to international practices, innovative research, and interdisciplinary culture in the specific thematic area, which in this case is smart cities.

A. Czech Technical University (CTU)

CTU (www.cvut.cz) is located in Prague, Czech Republic. CTU is the top engineering university in the Czech Republic. It has eight faculties (colleges) with a total student enrollment of 21,000. The Faculty of Transportation Sciences (FTS) offers Bachelor, Master and Ph.D. degrees in transportation. FTS has departments offering courses in Traffic Engineering, Intelligent Transportation Systems, Logistics, Air Transportation and others.

B. The University of Texas at El Paso (UTEP)

UTEP (www.utep.edu) is a public university in the State of Texas. It is part of the University of Texas System. The UTEP campus is located on the U.S.-Mexico border, at the western end of Texas. The university has an enrollment of approximately 25,000 students. The College of Engineering at UTEP has eight academic departments with approximately 3,500 students.

C. Dual Master Degrees Program

Since 2010, CTU's Faculty of Transportation Sciences and UTEP's College of engineering have successfully collaborated on the Transatlantic Dual Masters Degree Program in Transportation Sciences and Logistics Systems [1], known simply as Transportation & Logistics DMP in this paper. The European Commission's Directorate General for Education and Culture (DG EAC) and the U.S. Department of Education funded the program from 2010 to 2015¸ as part of the EU-U.S. Atlantis Program. This was the first DMP at CTU. It was also the first program of its kind in The University of Texas System. The Transportation & Logistics DMP has graduated 14 students from CTU and 3 students from UTEP. Given the

[1] Ruey Long Cheu is with the The University of Texas at El Paso, TX, USA (email: rcheu@utep.edu).
[2] Tomas Horak is with Czech Technical University, Prague, Czech Republic (email: horaktom@fd.cvut.cz)
[3] Carlos Ferregut is with The University of Texas at El Paso, TX, USA (email: ferregut@utep.edu).

[4] Miroslav Svitek is with Czech Technical University, Prague, Czech Republic (email: svitek@fd.cvut.cz)
[5] Michal Postranecky is with Center of City of the Future, Czech Institute of Informatics, Robotics and Cybernetics, Czech Technical University, Prague, Czech Republic (email: postranecky@ciirc.cvut.cz)

viability of the Transportation & Logistics DMP and recognizing the new global trend towards developing smart and resilient cities, both CTU and UTEP agreed to revise and expand the dual master degree program to reflect the current need to educate professionals in the growing field of smart cities engineering and science, which encompasses transportation and logistics. The experience gained by the program leaders from 2010 to 2018 has been instrumental in the design of the new DMP curriculum and implementation process.

D. Objective and Outline of Article

The objective of this article is to report the development of this new DMP, to share the program's structure, study plan and courses, to trigger discussion and to receive feedbacks from the experts in the related fields. In the remaining parts of this article, the authors describe the process of developing this new program, highlighting how this new program is different from the Transportation & Logistics DMP. The authors also present the program structure and study plan, followed by brief outlines of the smart city related courses created for the program. The authors also introduce the laboratory facilities that will be used for teaching and research. Finally, the authors share the expected challenges to the successful implementation and long-term sustainability of the new program.

II. DEVELOPMENT PROCESS

Prof. Miroslav Svitek from CTU is one of the pioneers of smart cities in the Czech Republic. He is the President of the Czech Smart City Cluster (CSCC) that includes major Czech universities and more than thirty companies (www.czechsmartcitycluster.com). The Cluster is an important entity involved in smart cities implementation in the Czech Republic.

The CSCC is based in the Czech Institute of Informatics, Robotics and Cybernetics (CIIRC) (www.ciirc.cvut.cz) and participates in the Center of Cities of the Future (CCF). CSCC closely co-operates with the Union of Towns and Municipalities (UTM) in the Czech Republic that includes all municipalities in the Czech Republic. This arrangement allows to link industry (CSCC), research and development (CCF) and users (UTM).

The concept of smart cities was introduced by Prof. Miroslav Svitek from CTU to UTEP faculty when he delivered a seminar at UTEP College of Engineering in April 2014. In August 2014, professors from Civil Engineering, Computer Science, Electrical and Computer Engineering, Industrial, Manufacturing and Systems Engineering departments at UTEP formed a special interest group named Smart City Community (http://expertise.utep.edu/communities/smartcities). The group soon began discussions and visits with Prof. Victor Larios at University of Guadalajara (UdeG), Mexico, who was instrumental in making the downtown of the City of Guadalajara the first IEEE designated smart cities test site, and whose Center of Smart Cities Innovation serves as the living laboratory on UdeG campus. With internal funds provided by UTEP and an external grant from Partners of the Americas Foundation, UTEP and UdeG began a bi-directional smart cities study abroad program in June 2016, with CTU faculty's participation in several lectures, sharing the experience in Europe.

In December 2016, UTEP, together with three other partnering universities in the United States established the Center for Connect Cities for Smart Mobility towards Accessible and Resilient Transportation (C2SMART), with five years of funding support from U.S. Department of Transportation.

In 2017, the U.S. National Science Foundation awarded UTEP an International Research Experience for Students (IRES) project to bring 10 graduate and Ph.D. students per year for three years to UdeG for six weeks to conduct research in the Center of Smart Cities Innovation.

The smart cities education and research activities at UTEP have accelerated to the level that both CTU and UTEP desired to have a collaborative smart cities project. The team took advantage of the successful collaboration in the Transportation & Logistics DMP and replaced it with the International Dual Master Degrees Program in Smart Cities Science and Engineering, denoted simply as Smart Cities DMP in this article.

III. UNIQUENESS OF THE PROGRAM

The new Smart Cities DMP differs from the Transportation & Logistics DMP in several ways:

- The Smart Cities DMP is opened to graduates from all the departments in the College of Engineering at UTEP and to non-UTEP graduates who have bachelor degrees in any engineering and computer science discipline the Transportation & Logistics DMP only accepts civil engineering and industrial engineering graduates. It is also opened to students
- The degree plan is integrated with the new courses created by Faculty of Transportation Sciences at CTU and courses taught by the Computer Science, Electrical and Computer Engineering, Civil Engineering, Industrial, Manufacturing and Systems Engineering departments at UTEP.
- CTU has engaged the participation of CIICR, a university level institute, to support the research component of the program. Through CIICR, student projects will have stronger linkages with the industry in Europe.

IV. PROGRAM STRUCTURE

A. Name of Program and Degree Offered

The proposed program is officially called International Dual Master Degrees Program in Smart Cities Science and Engineering. Students who successfully complete all the requirements for the program earn two degrees:

- Master of Science in Engineering (MSE) from UTEP; and
- Master of Engineering in Technology in Transportation & Telecommunications (METTT) from CTU.

The MSE degree at UTEP is an existing degree that requires 33 Semester Credit Hours (SCH) of coursework. This is equivalent to taking and passing 11 graduate courses. At UTEP, 1 SCH is equivalent to 15 contact hours. UTEP will create a smart cities concentration under MSE specifically for this Smart Cities DMP.

To earn a METTT degree from CTU, a student must complete and pass 120 European Credit Transfer System (ECTS) credits Graduate courses at CTU generally range from 2 ECTS to 6 ECTS. The METTT is also an existing degree at CTU. CTU will create a new study program in Smart Cities to accommodate the Smart Cities DMP.

In 2010, CTU and UTEP compared contact hours and student workload, and determined that 1 SCH is equivalent to 4 ECTS credits.

B. Program Objectives and Outcomes

The Smart Cities DMP has 3 educational objectives:
1. To prepare students for careers that involve the planning, design, implementation and operation of smart cities;
2. To expose students with knowledge of science and engineering to international practices, innovative research, and interdisciplinary culture that will facilitate the implementation of smart cities services; and
3. To provide a rigorous and yet flexible smart cities curriculum that will meet the needs of graduate students in their respective disciplines.

To achieve the above objectives, the authors defined the outcomes the graduates of this program should acquire:
1. Have knowledge on the concept and challenges of smart cities across the world;
2. Have the ability to apply science and engineering knowledge and skills to create smart cities solutions;
3. Have the ability to work in an interdisciplinary team;
4. Have the ability to communicate ideas across cultures and disciplines.

C. Program Structure

To meet each university's degree requirements, the academic credits (or knowledge) earned by a student toward his/her master degrees are divided into three parts: core courses, technical courses and research. Core courses teaches fundamental knowledge in smart cities which students from all disciplines should have. Technical courses are related to smart cities but they are tailored to students of a specific discipline, background or career interest. Technical courses are graduate level elective courses offered by the Civil Engineering, Computer Science, Electrical and Computer Engineering, and Industrial, Manufacturing and Systems Engineering departments at UTEP. At CTU, elective courses replace mandatory courses in a fixed curriculum taught by various departments in the Faculty of Transportation Sciences. For example, a student who has a Bachelor of Science degree in Computer Science will take the technical courses offered by the Computer Science Department. However, this student must take all the core courses with all students in this program (who may have background in other disciplines). The research project is for the student to demonstrate how he/she can apply what he/she learned in finding a solution to a smart cities problem. The distribution of credits among core courses, technical courses and research are in Table I. A student may take a course in one university and transfer the credits to the partner university.

TABLE I
DISTRIBUTION OF CREDITS

University	CTU (ECTS)	UTEP (SCH)
Core courses	60	18
Technical courses	48	12
Research	12	3
Total in degree plan	120	33

D. Study Plan

The DMP works by allowing students to transfer the courses they take in one university to the partner university and count the credits earn as part of the credits required to earn a degree at each institution. Therefore, the student is able to earn two degrees in a shorter time and lower costs compared to studying at two universities separately. In this DMP, study plans have been designed for students who start the program at CTU and UTEP respectively. Tables II and III show the study plans for student who start at CTU and those who start at UTEP respectively.

TABLE II
STUDY PLAN FOR STUDENTS WHO START AT CTU

Year (semester)	Univ. attended	Credits earned	Credits earned in CTU	Credits earned in UTEP
1(1)	CTU	30 ECTS	30 ECTS	*7.5 SCH*
1(2)	CTU	30 ECTS	30 ECTS	*7.5 SCH*
2(1)	UTEP	9 SCH	*36 ECTS*	9 SCH
2(2)	UTEP	9 SCH	*24 ECTS*	9 SCH
Total	-	-	120 ECTS	33 SCH

The credits in bold denote transferred credits. A student may transfer fewer credits earned from one university to another. 1 SCH is equivalent to 4 ECTS.

TABLE III
STUDY PLAN FOR STUDENTS WHO START AT UTEP

Year (semester)	Univ. attended	Credits earned	Credits earned in CTU	Credits earned in UTEP
1(1)	UTEP	9 SCH	*36 ECTS*	9 SCH
1(2)	UTEP	9 SCH	*24 ECTS*	9 SCH
2(1)	CTU	30 ECTS	30 ECTS	*7.5 SCH*
2(2)	CTU	30 ECTS	30 ECTS	*7.5 SCH*
Total	-	-	120 ECTS	33 SCH

The credits in bold denote transferred credits. A student may transfer fewer credits earned from one university to another. 1 SCH is equivalent to 4 ECTS.

E. Core Smart Cities Courses

The program will offer a total of six core smart cities courses. The following three courses were created by CTU:
- Smart City Design: Advanced smart city data collection (drones, smartphones, satellite systems, etc.), transmission (telecommunication technologies) and processing (artificial intelligence algorithms); smart city performance analysis (resilience, safety, reliability, integrity); smart city design UML (Unified Modelling Language); multi-agent systems (MAS), design of specific smart city solutions [2] [3] in the field of public administration, cyber and energy infrastructure, mobility, intelligent buildings, water and waste management; case studies – best practices from

Europe, United States, China and Latin America.

- Future Cities Laboratory: Creation of virtual and augmented urban models ("twin" models of urban structures of all types or their parts); practical use of artificial intelligence and virtual/augmented reality to simulate different city processes/scenarios (transportation, energy, environment, etc.); modelling of smart street with connected smart elements like street lighting, bins, signs, benches, displays and more.
- Sustainable Cities and Regions: Sustainability and environment - examples from transportation, buildings, energy, water and waste management systems; social and culture factors – quality of life, resident engagement, social cohesion; economy and logistics – sharing economy, last mile goods distribution, effective city management; ways of addressing the long-term sustainability of cities.

The following three courses were revised from the existing courses taught at UTEP with enhanced smart cities content:

- Smart Cities Fundamentals: Introduces the students to the interdisciplinary concept of smart cities, with focuses on smart building, smart healthcare and smart mobility. In addition to attending lecturer and field trips, students will acquire hands-on experience in working in an interdisciplinary, international project team to develop a prototype smartphone application towards the implementation of smart building, smart healthcare and smart mobility
- Data Integration and Exchange for Smart Cities: This course will introduce cyberinfrastructure foundations and scientific applications with a focus on semantic web, technologies and current research trends in the field. Hands-on activities are used to illustrate practical aspects of cyberinfrastructure.
- Systems Engineering for Smart Cities: Introduction to the key concepts, processes, and process activities carried out by systems engineers. Fundamentals of architecting and engineering of large and complex development projects. Software tools are covered with emphasis on architectural analysis and design, functional design alternatives, and key architectural attributes.

V. RESEARCH PROJECTS AND SUPPORTING FACILITIES

A strong motivation to create this DMP is that it presents the opportunity for participating professors from CTU and UTEP to collaborate on research projects. Research collaborations have started in the past by jointly supervising students on thesis/projects. Each student must complete a research project in two semesters. This project is written into the student's CTU diploma thesis and is also counted as UTEP graduate project report. Upon completion of the project, the student must pass an oral defense examination in front of a committee formed by professors from CTU and UTEP. To earn a degree from CTU, the student also has to pass the State Exam (an oral exam) which tests the candidate's competency in three core courses: Smart Cities Fundamentals, Smart Cities Design and Sustainable Cities and Regions.

The CIICR, the flagship research center at CTU, will share its resources, in particular the Center of City of the Future (CCF), an independent center within CIIRC.

The CCF presents the city as a whole complex system and its individual subsystems, as well as a part of a larger geographical or administrative unit. It introduces the city and its surroundings as a permanently evolving living organism and a complex social physical-cybernetic system with its own unique identity [4]. The aim is to investigate not only the physical and virtual structure of the urban space, but also the entire community of these structures.

The virtual model of Prague and the model of the selected area of the Prague 6 district will be the important part of the CCF. The resulting simulations and presentations at the City of Prague will be augmented above the orthomap of the whole city and its surroundings, and above the physical model of Prague 6 district including the CTU campus. Both models will serve to visualize processes occurring in the area based on combined data outputs from various simulation models. The aim is to gain a deep understanding of processes and phenomena that occur within urban structures and to discover their causes when using new resources (such as AI) and to better understand them through improved techniques of visualization. Also, other physical models of a particular type of urban space, connected to remote real-time data inputs, will be installed in CMB's premises.

CCF will serve as the teaching laboratory of one core course and will be the core research facility for student research. It is a virtual testbed for transforming cities into smart cities and as a testing ground for new technologies. This laboratory will have data links with their counterparts in the Civil Engineering, Computer Science, and Electrical and Computer Engineering departments at UTEP, creating "twin" and virtual networks of urban infrastructures and info-structures.

CTU, through CIICR, participates in the Smart Prague project (www.smartprague.eu) which aims to make Prague a smart city. The smart Prague concept has six areas: mobility of the future, smart buildings and energy, waste-free city, attractive tourism, people and urban environment and data arena.

UTEP has recently signed a memorandum of collaboration with the City of El Paso. Researchers in the College of Engineering at UTEP are working with staff in the City of El Paso on five projects that will help the city to be smarter in delivering its services to the residents. Some of these projects will become research projects that will involve the DMP students co-supervised by UTEP and CTU professors. By doing so, the City of El Paso may be considered as the living laboratory for UTEP and the City to test out new technologies in transforming El Paso into a smart city.

VI. CHALLENGES

Despite the experience in implementing the Transportation & Logistics DMP, the authors still faced many challenges in the development of this Smart Cities DMP. They include academic, interdisciplinary cultural, budget and administrative challenges. The major ones are highlighted here.

The first challenge was to have all the interested professors understand the concept of smart cities, have common vocabulary so that they can communicate effectively. Face to face meetings and workshops helped to facilitate this process. These activities are documented in [5].

As smart cities is a very broad topic, the second challenge was to narrow the focus to a few strategic areas, based on the expertise of the professors, potential collaborators in the cities and the industry, and potential sources of funding, the group has selected three strategic areas in which courses and projects are built upon: smart mobility, smart building and smart healthcare.

Having overcome the first two challenges, the third and consistent challenge is financial support for students. Unlike the Transportation & Logistics DMP which was funded by the EU-U.S. Atlantis Program from 2010 to 2010, students who enrolled in this Smart Cities DMP will initially be partially funded by CTU and UTEP through scholarships. International students who study at The University of Texas System have the additional burden of purchasing health insurance from a few recognized U.S. providers. The authors are trying to demonstrate the benefits of this Program to students and professors, so that when funding opportunities arise, the proposal from CTU-UTEP will be very competitive.

Another issue is student recruitment, which is closely related to the cost of study abroad and the amount of financial support a student could receive. Our historical data has shown that more CTU students studied at UTEP than vice versa. CTU, because of the good experience of past UTEP students who studied there, is well known at UTEP. However, more students chose to go to CTU for one semester of exchange than two semesters of DMP because of the out-of-pocket living cost of additional semester. Because of Czech Republic's accreditation requirement, CTU is unlikely to offer online course to ease the need of UTEP students traveling abroad (to reduce cost of living). In the short term, having more generous financial support from UTEP's Office of International Program is the only temporary solution.

VII. CONCLUDING REMARKS

Prague and El Paso are two cities with different climate, history, culture, lifestyle, economic development, standard of living, etc. They also face their own geographical, political challenges and natural resource constraints. By studying two different cities, students will acquire international experience which will make them more innovative in coming out with smart cities solutions.

The smart cities concept demands a multidisciplinary approach. It also requires the participation and close collaboration of the university, city, residents, and industry stakeholders. Similarly, a smart city education program must involve these stakeholders. In this Smart Cities DMP, CTU and UTEP have designed a program that involves professors and students in several departments. The cities and industry will participate in research projects, using interdisciplinary research facilities on campuses or the cities as the living laboratories. Through these projects, researchers at CTU and UTEP will work with the city officials to engage the residents in helping to test and develop smart cities solutions.

REFERENCES

[1] R. L. Cheu, C. Ferregut, L. Bina, H. Novakova, T. Horak, A. Novak, A. Hudak and S. Aguirre-Covarrubias (2012). Transatlantic dual masters degree program in transportation and logistics systems: the first two years of implementation. Transportation Research Record, No. 2328, pp. 1-8.

[2] M. Svitek (2014). Telematic approach into program of smart cities. Proceedings of the 7th Euro American Conference on Telematics and Information Systems (EATIS), Valparaiso, Chile.

[3] O. Pribyl O. and M. Svitek (2015). System-oriented Approach to Smart Cities. Proceedings of the IEEE 1st International Smart Cities Conference (ISC2), October 25-28, 2015, Guadalajara, Mexico.

[4] M. Postranecky and M. Svitek (2017). Conceptual Model of Complex Multi-agent System Smart City 4.0. In: V. Marik, W. Wahlster, T. Strasser, P. Kadera (eds). Industrial Applications of Holonic and Multi-Agent Systems. HoloMAS 2017. Lecture Notes in Computer Science, Vol. 10444. Springer, Cham.

[5] N. Villanueva-Rosales, R. L. Cheu, A. Gates, N. Rivera, O. Mondragon, S. Cabrera, C. Ferregut, C. Carrasco, S. Nazarian, H. Taboada, V. Larios, L. Barbosa, M. Svitek, O. Pribyl and T. Horak (2015). A collaborative, interdisciplinary initiative for a smart cities innovation network. Proceedings of the IEEE 1st International Smart Cities Conference (ISC2), October 25-28, 2015, Guadalajara, Mexico.

Ruey Long Cheu (M'2001, SM'2017) earned his Ph.D. in Engineering degree at University of California, Irvine in 1994. He was a professor at The National University of Singapore. He joined The University of Texas at El Paso (UTEP) in 2006 and is currently a Professor in Civil Engineering in the College of Engineering. He is a Fellow of the American Society of Civil Engineers and a Senior Member of IEEE. He is leading the smart cities initiatives at UTEP.

Tomas Horak received his Ph.D. degree in Transportation sciences & Telecommunications from Czech Technical University (CTU) in 2013. From 2013 to 2017 he was an Assistant Professor with the Faculty of Transportation Sciences at CTU. From 2017 he serves as Associate Professor in the

same faculty. He is also the Assistant Dean for International Relations since 2014.

Carlos Ferregut earned his Ph.D. in Civil Engineering degree from the University of Waterloo. He has been a professor at UTEP since 1990. He is currently the Associate Dean for Strategic and Global Initiatives in the College of Engineering at UTEP.   He is instrumental in initiating and growing international education and research collaborations for the College of Engineering at UTEP.

Miroslav Svitek received his Ph.D. in Radio Electronics degree from Czech Technical University (CTU) in 1996. From 2002 until now he has been a professor at the Faculty of Transportation Sciences at CTU. He served as the Dean of Faculty of Transportation Sciences at CTU from 2010 to 2018. He is the President of the Czech Smart City Cluster, President of the Association of Transport Telematics, President of the National Association for Electromobility, and Member of the Engineering Academy of the Czech Republic.

Michal Postranecky received his M.Arch degree in Architecture & Urban Planning from Czech Technical University (CTU) in 1983. He has been an owner, partner or managing director of several architectural, urban design and planning consulting companies. He designed many buildings in Europe and the United States. From 2017, he holds joint appointment as the Researcher & Head of Center of City of Future in Czech Institute of informatics, Robotics and Cybernetics in CTU.