

A REVIEW OF LITERATURE IN DISCRETE EVENT SIMULATION ON SUSTAINABILITY IN THE TRANSPORT SECTOR

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RESUMO

Este trabalho apresenta uma revisão de literatura na área de simulação a eventos discretos aplicada à sustentabilidade no setor de transporte. Foi utilizada a base de dados bibliográfica SCOPUS, onde foram selecionados todos os campos de pesquisa disponíveis. Os resultados mostraram que este problema é abordado por diferentes segmentos, desde o supply chain até a sustentabilidade em rodovias e estradas. Por fim, foi possível identificar os principais assuntos abordados, buscando estudar a evolução do tema ao longo do tempo, e identificar quais países mais publicaram nesta área.

PALAVRAS CHAVE. Simulação a eventos discretos, Sustentabilidade, Transporte.

Área principal: SIM - Simulação.

ABSTRACT

This work presents a literature review on the Discrete Event Simulation (DES) area applied to sustainability in the transport sector. The bibliographic database SCOPUS, where were selected all the available search fields, was used. The results showed that this problem is used by different fields, from supply chain up to sustainability in highways and roads. Finally, it was possible to identify the main issues handled, trying to study the evolution of the topic over time, and identify which countries published in this area.

KEYWORDS. Discrete event simulation. Sustainability. Transport

Main area: SIM - Simulation.

1. Introduction

In recent work, Fakhimi et al. (2013) presented a review of the literature with the aim at providing a synthesized overview of simulation and modeling approaches that dealt with problems of sustainability. In their study, the authors grouped the works by application areas where the transport sector occupied the last position. According to findings, around 42% of studies have developed a model for manufacturing sector, 35% are related to ecosystem models, 14% of models have relation to regional and urban modeling, 5% of papers have developed a model for agriculture sector, and 3% also used modeling techniques to address sustainability in the transport sector.

However, according to recent data from the International Energy Agency (IEA), the two sectors responsible for the larger share of CO₂ emissions in the world are: electricity generation and heating, with 42%, followed by the transport sector, with 23%. It is still worth noting that the transport sector had a growth rate considered high (64%) between 1990 and 2012, driven, mainly, by the emissions of the road sector (IEA Statistics 2014). Thus, despite the transport sector have a significant participation in the global CO₂ emissions, the results found in the work of Fakhimi et al. (2013) showed no relationship with these data. In other words, we are not here questioning the results of the authors, but raising the possibility of the publications may not be following, in a correlated way, the focus of the question.

Given the importance of transport and its participation in the global carbon emissions, the present work aims at mapping and quantifying the articles of the intersection of the transport and sustainability fields that use simulation, especially discrete event simulation. The article is structured as follows: section (2) describes the methodology used for literature review. The next sections, 3 and 4, deal with the results and final considerations, respectively.

2. Methodology Used for Literature Review

Our literature review methodology presented was based on the work of Méxas, Quelhas, and Costa (2012). The main search terms were based on the production of Fakhimi et al. (2013). Our work adopts SCOPUS as a bibliographic database containing abstracts and citations for academic journal articles. The research had as initial parameters articles and reviews, from 1960 to Jan / 2015, and works in English. All areas available in the database were selected (Life Sciences, Health Sciences, Physical Sciences and Social Sciences & Humanities).

The terms 'sustainabl*' AND 'simulation*' were searched, at the database, in titles, abstracts and keywords of works, which resulted in 3,860 articles. The asterisk is useful to investigate similar words, in this case, changing only the end of them. In this way, the research might cover some variations of the examined terms. The initial search returned a large number of publications; therefore, another investigation was conducted using only the keywords. Thus, the new search returned 1,194 publications.

The following step consisted of the refinement of the articles found. The term 'transport *' was added to the previous ones by means of the connector AND; this resulted in 80 articles. This process was repeated so as to include the following terms: 'agriculture', 'region* modeling' OR 'urban modeling', 'ecosystem' OR 'climate change' and 'manufacturing'. The subsequent step was to analyze the abstracts of the articles returned by the survey in the keywords in which we used the search term: 'sustainabl*' AND 'simulation *' AND 'transport *'. This analysis let us separate 35 articles, which deal with the theme, and group them by application.

At the same time, another research was made, on the same database, in articles and reviews written in English in the same period of the previous one. However, this time, the articles were selected using the search term: "discrete event simulation" AND "sustainabl*". This resulted in a total of 20 articles, which were separated by year of publication and, subsequently, by countries' participation in the works. This participation was measured based on the number of publications of

the authors in the works and their affiliations. Combinations of the term “discrete event simulation” with “green supply chain”, “carbon emissions” or “transport” searched in title, abstract and keyword were also made. The search filter includes all categories as in the previous one (Physical Sciences, Social Sciences, Life Sciences, Health Sciences). Table 1 shows the result of each combination.

Table 1: Results for search term in SCOPUS

Search Term	Publications
“sustainabl*” AND “simulation*”	1,194
“sustainabl*” AND “simulation*” AND “transport*”	80
“sustainabl*” AND “simulation*” AND “agriculture”	89
“sustainabl*” AND “simulation*” AND “region* modeling” OR “urban modeling”	33
“sustainabl*” AND “simulation*” AND “ecosystem” OR “climate change”	83
“sustainabl*” AND “simulation*” AND “manufacturing”	44
“discrete event simulation” AND “sustainab*”	20
“discrete event simulation” AND “green supply chain”	4
“discrete event simulation” AND “carbon emissions”	8
“discrete event simulation” AND “sustainab*” AND “transport*”	2

Thus, it can be said that this research had three specific objectives. The first purpose was to identify the number of publications in the intersection of the spheres of sustainability and simulation for transport, since it was observed, in the work of Fakhimi *et al.* (2013), a low number of publications covering these spheres. Another goal was to analyze these works regarding simulation, transport and sustainability, and group them into categories to map the application areas. Lastly, a more refined search was done, with the aim of collecting works that use discrete event simulation related to sustainability.

3. Results

First, it was done a quantitative survey of publications, dealing with simulation and sustainability in different areas. Once this has been done, we refined the search to articles of discrete events simulation with sustainable aspects.

3.1 Survey of Publications Concerning Transport

One purpose of Fakhimi *et al.* (2013) was to identify applications of simulation techniques in different sectors focusing on sustainability. In this survey, 69 publications, which were divided into different sectors, were found by means of investigation done at the basis of ISI Web of Science. The results showed the transport sector with only 3% of publications, preceded by 42% of articles referred to manufacturing, 35%, to ecosystem and climate change, 14%, to region and urban modeling, and 5%, to agriculture.

This motivated us to verify whether this result would be similar to those of the same sectors in another base, particularly the transport sector, which is the focus of this work. For this, a similar survey was conducted, however, on the SCOPUS database. This time, the result returned a significantly higher number of publications in all areas, especially in transport. That was an expected return because all areas available were covered on SCOPUS, while Fakhimi *et al.* (2013) approached the operations research management science area. Concerning the sphere of simulation and sustainability, agriculture returned the largest number, with 89 publications, while the area of urban and regional models resulted in the lowest, with 33. The transport area returned 80 articles.

Figure 1 describes the values in relation to the application sectors. Note that there is no straight correlation among the sectors of application found on our results and those of Fakhimi *et al.*

(2013), when compared with those presented by the IEA, with respect to the main CO₂ emitters.

However, more similar, the results found now (Figure 1) show the transport sector in third position. That is, the transport sector appears as a matter of interest when the theme is sustainability, demonstrating a greater similarity between the number of works concerning sustainability and the data submitted by the IEA for gaseous emissions of carbon.

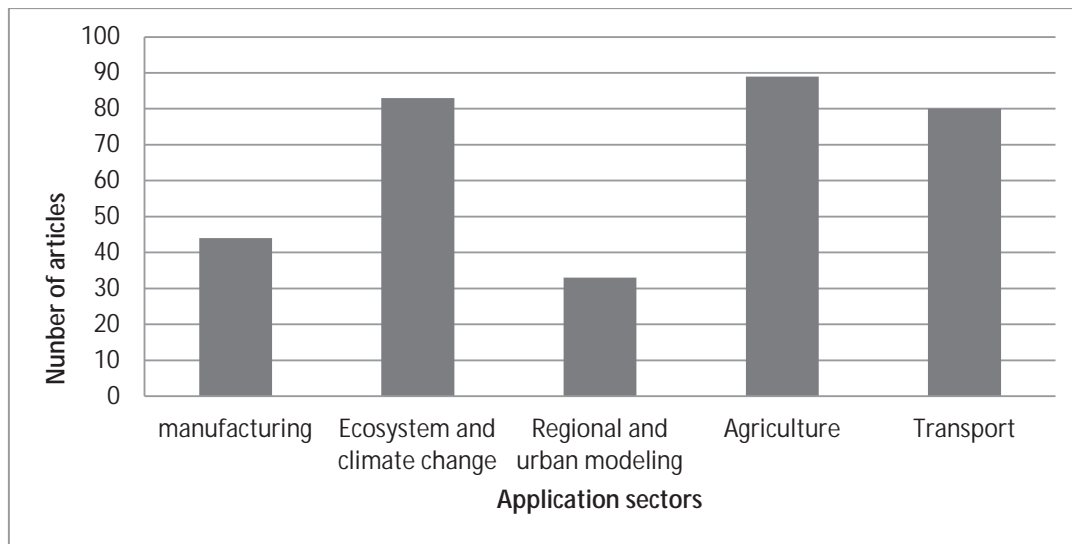


Figure 1: Application of simulation techniques concerning sustainability in different sectors, SCOPUS database.

The application sectors shown on work of Fakhimi et al. (2013) follow a descending order of presentation on number of publications. However, the absolute values were different to the results found in this work. Thus, Figure 1 follows the same layout of presentation of the sectors that the work of the authors mentioned above. In their study, the transport appeared with the lowest number of publications among sectors. Our study points to this sector as the third largest in number of articles.

Next, we conducted a refinement of the research in publications returned by the transport sector. To this end, the abstracts of 80 articles were read in order to see if they fit in the research proposed, that is, if they dealt with simulation, sustainability and transport in their content. This total was selected, and 35 articles, which had to do with the aim, were obtained. Soon after, they were grouped by similarities of application, reaching the following categorization: Sustainable transport; Sustainable mobility; Logistics systems; Highway and Road Sustainability; Supply chain; Manufacturing; and Allocation. As shown in Figure 2, most of the articles concerned the issues of Sustainable transport and Sustainable mobility in this screening, while a minority presented questions about Supply chain, Manufacturing and Allocation.

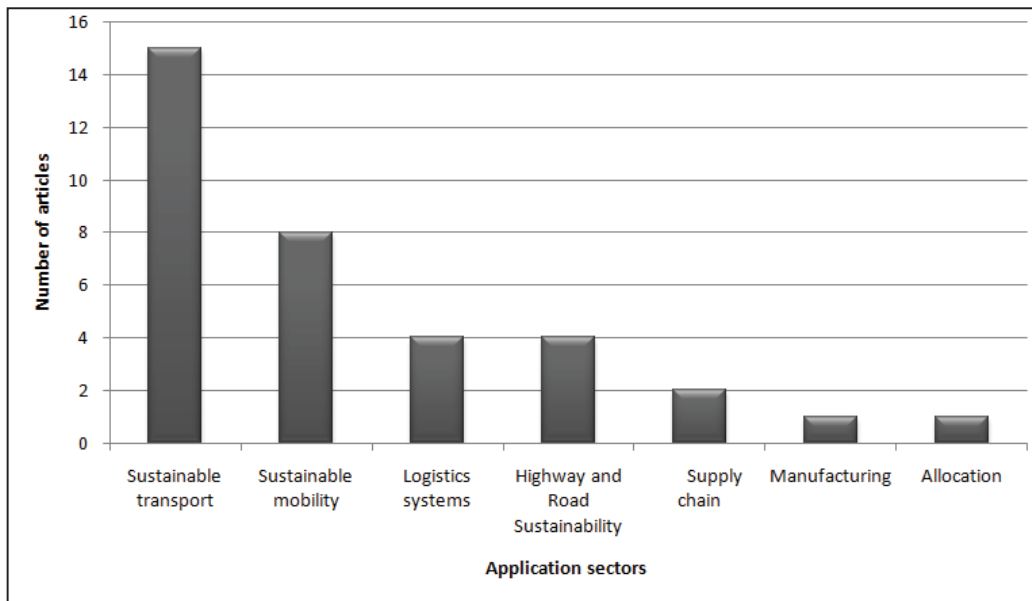


Figure 2: Number of articles by application sectors.

3.2 Articles about Discrete Event Simulation with Sustainable Aspects According to the Year

In this step of the survey, the focus was directed to search for articles which use discrete event simulation (DES) with sustainable approach in the areas of supply chain, transport and greenhouse gas emissions. Within this context, Figure 3 shows the evolution of the number of publications over time.

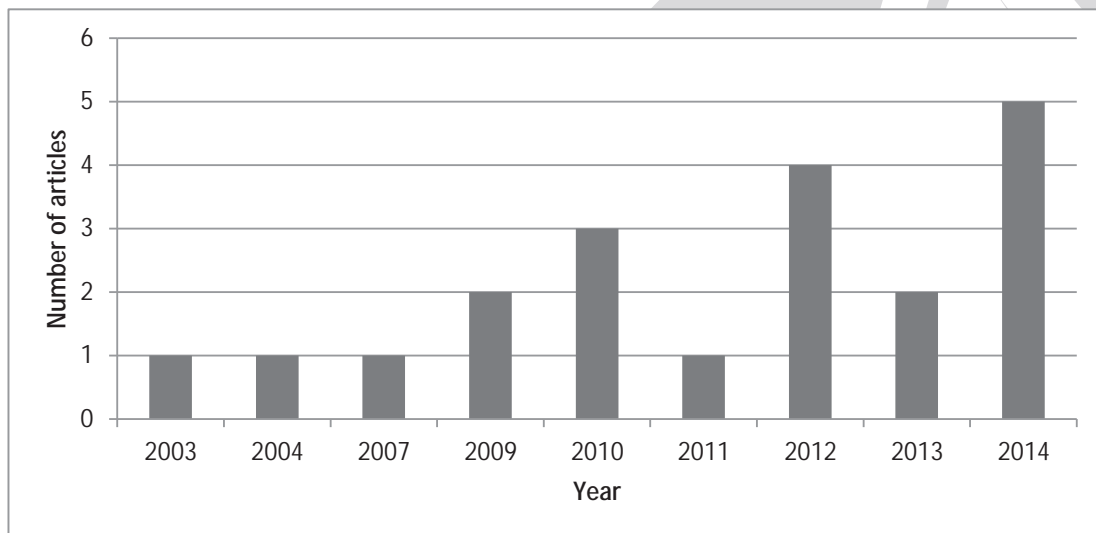


Figure 3: Number of articles using the search terms with DES in keywords published per year.

The issue began to be more explored from 2003, probably influenced by the United Nations World Summit on Sustainable Development, which took place in 2002, also known as Rio +10 held in Johannesburg. Ten years after this conference, it was the Rio +20, in 2012, coinciding with a peak

of publications in the same year. Lastly, 2014 presents the largest number of articles which coincides with the year subsequent to that of the creation of the ISO 14067 standard, carbon footprint, in 2013.

The same articles were used to investigate the participation of each country in that period, based on the number of publications of authors and their affiliations in each work, as shown in Figure 4. The United States appear as the country with the highest occurrence, with 14 participations, followed by Japan and Ireland, with 6 each. Lastly, Chile and Australia appear with the fewest number, with 1 and 2 participations, respectively. It is worth mentioning that some articles were written, in association, by authors of different affiliations.

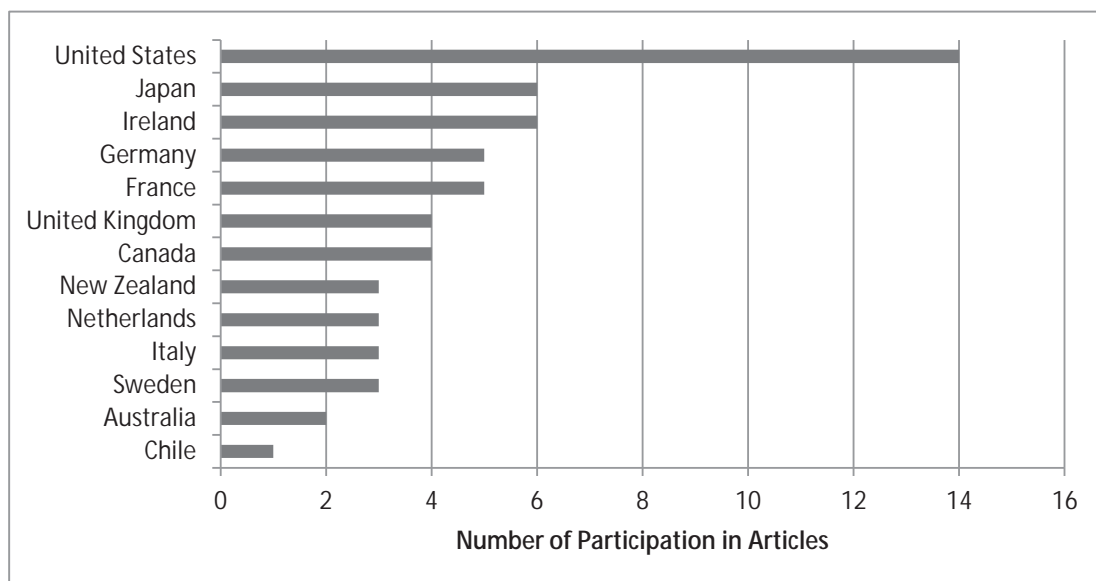


Figure 4: Number of participation in articles using the search terms with DES in keywords, separated by nationalities between 2003 and 2014.

The articles listed in Table 1, in which appears the term "discrete event simulation", were surveyed to determine the subjects covered. This way, Table 2 was developed to group these publications by similarity.

Table 2 shows that, of all evaluated publications, mostly come from Manufacturing, with 10 articles, followed by Logistics, with 9 articles, showing various applications of the use of discrete events simulation with regard to sustainability. 4 articles classified by subject as Others were also identified, and deal with sustainability within discrete event simulation in other aspects.

Additionally, the recent work of Rangel and Cordeiro (2015) demonstrated how calculations of greenhouse gas emissions from transport in logistics systems can be analyzed with DES models. The authors compared trade-offs of economic and environmental variables, in contrast to what is usually done in these types of systems, such as comparing economic variables with inventory variables.

Table 2 – Tabulation by subject in SCOPUS

SUBJECT	ARTICLE(S) IDENTIFIED(S) IN SCOPUS
Logistics	(Acaccia, Micheline, and Qualich 2007); (Byrne, Heavey, Ryan, and Liston 2010); (González and Echaveguren 2012);(Jaegler and Burlat 2012); (Jaegler and Burlat 2013); (Seay and Badurdeen 2014); (Tromp, Rijgersberg, and Franz 2010); (van der Vorst, Tromp and Zee 2009); (Rios, Stuart, and Grant 2003);
Manufacturing	(J Pollock, Ho, and Farid 2012); (Jaegler and Burlat 2013); (James Pollock, Ho, and Farid 2013); (Larek, Brinksmeier, Meyer, Pawletta, and Hagendorf 2011) (McNally and Heavey 2004); (Miller, Pawloski, and Standridge 2010); (Peng and Xu 2014); (Solding, Petku, and Mardan 2009); (Rios et al. 2003); (Sharda and Bury 2012).
Others	(Dawson and Spedding 2010); (Ghoreishi-Madiseh, Hassani, Mohammadian, and Radziszewski 2013); (Tsuda et al. 2014); (Wang, Brême, and Moon 2014).

4. CONCLUDING REMARKS

According to results of previous works, it was noted that, when dealing with sustainability, a few articles applied discrete event simulation. Within this context, we noted that very few works dealt with the question relating to transport. However, the transport sector is one of that represents a large part of greenhouse gases emissions, especially carbon emissions, according to recent data from the International Energy Agency.

Thus, within the results found in the fields of simulation and sustainability, 80 articles (24%), relating to transport, were obtained. This total was filtered and, subsequently, the works were grouped by similarities of application. Most of the articles addressed the issues of Sustainable transport and Sustainable mobility in this new screening. When the survey was directed to search for articles using discrete simulation, in the areas of supply chain, transport and greenhouse gas emissions, it was observed the evolution of the number of publications over time. Therefore, the results demonstrated that the subject began to be more explored from 2003, coinciding with the United Nations World Summit on Sustainable Development. The year 2014 was the one which presented the largest number of articles, probably influenced by the creation of ISO 14067 standard, carbon footprint, in 2013. Regarding the participation of each country in this period, the United States appear as the country with the highest participation, with 24% in publications, followed by Japan and Ireland, with 10% each.

As a result, this study presented a survey of literature review with interest in discrete event simulation, transport and sustainability areas. Consequently, it was possible to identify the main subjects discussed within these areas, seeking to study the evolution of the theme over time and map the countries that publish in this field.

The results of this work do not presume to point to a conclusive study or numbers that may demonstrate the final outcome of the matter. Our idea was to point out elements that can assist new researchers interested in exploring the subject and identify trends related to this field of study.

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