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Sustainability – Recommendations for an Electric Vehicle Manufacturing in Sub-Saharan Africa

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Abstract

Production locations in least developed countries need their own indicators to evaluate sustainability due to prevailing conditions. For this reason, we present a selection and extension of indicators for social and economic sustainability evaluation for production locations in least developed countries. These indicators are identified and tested based on existing sustainability evaluation methods and representative case studies. Since the battery electric vehicle is seen as the future, the case studies results are used to derive recommendations for an all-wheel lightweight commercial electric vehicle production in sub-Saharan Africa. This vehicle was developed to fit the needs of people living in rural regions of sub-Saharan Africa as well as to add local value to economically support the region.

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1. Introduction

The trends in the automotive industry towards sustainability, electric vehicles and the development of new markets are summarized in this paper. Therefore, we first show the influence of the automotive industry in developing and emerging countries, and then explain the potential of electric vehicles. Subsequently, methods for evaluating sustainability are presented. From this we derive the need for a concise evaluation of vehicle production in developing countries. This is based on the selection of indicators against which we evaluate reference productions. From this evaluation we derive recommendations for the 'aCar mobility' project. This use case is a multiple purpose all-wheel electric vehicle for people living in sub-Saharan Africa. With its special design it suits for transport of people, goods and local production. Further we derive general recommendations for a sustainable vehicle production in developing countries.

2. Vehicle Production in Least Developed Countries

2.1. Economic Growth through the Automotive Industry and Mobility

The automotive industry as a core manufacturing industry influences not only major economies like Germany, France, North America or Japan but also the economies in all parts of the world. This happens through the automotive industries global network, with its horizontal and vertical supply chains [1]. Emerging markets such as China and India record vehicle sales growth of approx. 212 % (China) and 105 % (India) in the period between 2008 and 2017 [2]. With the increasing demand Original Equipment Manufacturers (OEMs) set up new or enlarge existing production sites within these markets [3].

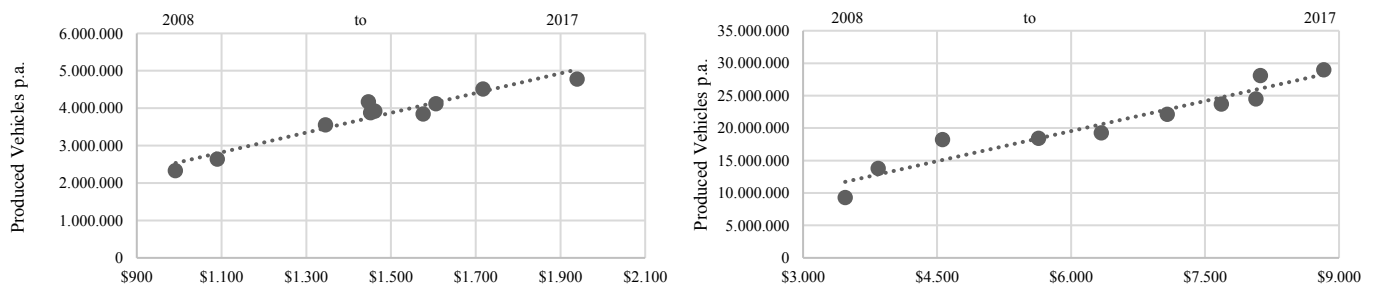


Fig. 1. Correlation of GDP per Capita and Vehicle Production Figures of India (left) and China (right) (Source: OICA).

Using the Pearson Correlation Coefficient (1) to evaluate the dependency of vehicle production and GDP per Capita the Pearson Correlation results in $r = 0.959$ for the Chinese market and $r = 0.958$ for the Indian market taking the years 2008 to 2017 into account. Therefore, it is valid to define the increasing GDP per Capita and the automotive industry as closely related (Fig. 1).

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} * \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (1)$$

Economies in least developed countries, such as many in sub-Saharan Africa, would like to benefit from an economic development through the automotive industry. Thus, they use different approaches to establish a domestic vehicle industry, for instance the New Automotive Development Plan in Nigeria [4 p.11] or state-supported automobile industries such as Kiira Motor Corporation in Uganda [4 p.14]. Hence, these countries plan to reduce their current vehicle import dependency [4 p.6]. For this purpose the automotive industry was among the first industry branches to be liberalized in India and China [3 p.4]. Commonly the least developed countries counter the strategy of OEMs to only export vehicles into small markets through tariff and non-tariff trade barriers [4 p.12–16]. With local content requirements pressure is put on manufacturers to transfer value creation and supply sources into these markets [5]. Thus, manufacturers are forced to invest in local supply chains [3]. As a result, manufacturers are challenged to establish profitable domestic locations for the expected small quantities.

2.2. Potential of Electric Vehicles

This domestic location demand stands in divergence to the sub-Sahara Africa Markets which consists of a multitude of small economies [4 p.7]. It is contrary to today's value creation, which takes place in few locations in automotive core markets [6]. Thus, the investment in final assembly lines commonly amounts more than 200 million € [7 p.19]. Therefore, automotive production innovation cycles are several years, with long production periods and low individualization [6]. Hence, striving for small series capability for future (European) vehicle production is suggested [6]. This is characterized by investment reducing combined with guaranteeing competitive quality level. With this small series capability a production in heterogeneous micro markets may be enabled. These micro markets are challenged commonly by high costs and lack of scalability [4 p.6].

Predestined automotive products for these micro markets are electric vehicles that can be produced profitable in small series through adaptable vehicle architectures and concepts [6]. Hence, market fluctuation of these micro markets and changing customer demand can be absorbed. Typical for this demand shift are the emerging markets customers whose buying behavior evolve. Exemplary is the shift from a price focus to a price-value focus in the passenger car segment in India. Additionally the demand in India of multi-utility vehicles has recently been redefined [1 p.9].

Despite this promising approach of small series electric vehicle production, local production in least developed countries is still characterized by low value added [8], which is contrary to a sustainable corporate strategy that includes local value adding [9].

2.3. Sustainability in Least Developed Countries

In order to assess the impact of local automobile production, we evaluate them against the background of sustainability. To this extend, we will first introduce the concept of sustainability and then present existing methods for assessing sustainability.

2.3.1. Theoretical Background on Sustainability

Sustainability research is made difficult by the lack of a uniform definition of the term sustainability. In academia, the description of sustainability in the 1987 Brundtland Report of the United Nations has become widely accepted [10 p.5]. The report defines that for sustainable development generations of the present may only satisfy their needs to the extent that the needs of future generations can also be met [11 p.8]. Sustainability is described in three dimensions: ecology, economy and social [11 p.32]. In 2015, the Agenda 2030 was developed. It contains 17 goals for sustainable development, which are valid for all countries with a term until 2030 [12 p.21–22]. The goals include the fight against poverty and hunger, as well as the promotion of education.

According to [13], industrialized countries are lagging in achieving their goals in the areas of responsible consumption and international development work, while least developed countries, especially in Africa, are failing in the fight against hunger and for security [13]. The following research focuses on the economic and social sustainability only, due to already existing research and standardized assessment of ecological sustainability.

2.3.2. Sustainability Assessment Methods

Different methods exist for measuring sustainability. Ahmadi [14] presents the Best Worst Method, Buys et al [15] the Sustainability Score Card, which are described detailed in the respective publications. Other methods include the Sustainability SWOT Analysis [16], the Sustainability Hot Spot Analysis [17] and the BellagioSTAMP [18]. Klöpffer's [19] Life Cycle Sustainability Assessment (LCSA), which consists of the life cycle assessment, a life cycle cost accounting and the social balance sheet, is most popular to evaluate sustainability. Reuter [20 p.31–42] extends the existing approaches in order to enable an evaluation of sustainability aspects for the selection of raw materials and technologies for electric vehicles.

Disadvantages of the methods are, among other things, only a qualitative assessment, the consideration of only two of the three dimensions, the required expert knowledge and the involvement of all stakeholders, as well as an insufficient degree of detail in the work steps and the lack of selection of indicators. In sum, there is no methodology for assessing the sustainability of production sites in least developed countries by now. We would like to close this gap by selecting suitable indicators for this evaluation. With the listed disadvantages of the existing methods a direct application is not possible.

Due to the transparency, the possibility of quantitative evaluation, the degree of awareness, the level of detail and the scope of the study, we use the LCA as a basis for evaluating the sustainability of production sites in developing countries.

3. Evaluation of the Impact of Vehicle Production

The method for determining recommendations for action for socially and economically sustainable vehicle production comprises four steps.

1. Literature analysis on sustainability indicator
2. Selection of indicator
3. Evaluation of existing vehicle production
4. Deriving recommendations for action

Beginning with a literature analysis on sustainability indicators we then select the indicators suitable to estimate the impact of a vehicle production.

The indicators are selected by answering four questions:

- a) Is the indicator relevant for production in developing countries?
- b) Is the indicator relevant for vehicle production?
- c) Is the indicator to be evaluated quantitatively?
- d) Are data available for quantitative evaluation?

In order to find the indicators, both literature and databases such as PROSA* were searched. The literature analysis was conducted by linking the search terms: ("Developing countries" OR "Emerging Market") AND (Sustainability OR Sustainable OR "Triple Bottom Line") AND (Method OR Assessment OR

Evaluation) AND (Manufacturing OR Production) in the database of ScienceDirect†.

Herby, the focus is on indicators from the economic and social dimensions. After this selection, we use these indicators to evaluate existing production sites of vehicle manufacturers over as long a period as possible. The selection of the use cases is based on available data on the production location and region-specific characteristic data, the timeframe of local production and geographical distribution. With the results, we develop recommendations for the production of the aCar.

3.1. Selection of Indicators to Evaluate Sustainability in Least Developed Countries

The selection of indicators is based on a literature search and includes only social and economic indicators [21–23], as standardized procedures already exist for assessing environmental sustainability. The indicators for the selection were evaluated based on four mentioned criteria: first the relevance of the indicators for production in least developed countries, second the relevance of the indicators for vehicle production, third the possibility of a quantitative evaluation and fourth the availability of data. With this approach 22 indicators were selected, which are divided into three stakeholders (employee, region / society and company) (Table 1).

Table 1. Selected Indicators for the Three Stakeholders.

Stakeholder	Indicator
Employee	Number of work accidents
	Access to medical institution
	Company's average wage vs. regional average wage
	Company's minimum wage vs. regional minimum wage
	Company's working hours vs. regional working hours
	Company's paid vacation vs. regional vacation
Society / Region	Illiteracy rate
	School attainment (primary/secondary)
	Number of schools
	Gross enrolment ratio
	People living in poverty
	Unemployment rate
	Workplaces in the company
	Workplaces in the company direct + indirect
	Workplaces in the automotive industry
	Road infrastructure
Fast-moving-consumer-goods market growth	
Company	Suppliers
	GDP per capita
	Automotive industry share of GDP
	Competitive market
	Profit

* <http://www.prosa.org/>

† <https://www.sciencedirect.com/>

The indicators of the stakeholder employees should ensure fair treatment of the employee and prevent exploitation. In addition, these indicators should also ensure sufficient safety for the employee. The indicators for society and the region describe the development of education, which is essential for sustainable development, the development of poverty, which is to be reduced in least developed countries, the development of jobs, the development of infrastructure and economic development. For the stakeholder company, the competitive market and corporate profit are considered.

It cannot be excluded, that other factors than the considered OEMs may influence the regional change in the indicators. Despite this, we assume that the automotive industry will have a strong impact, as GDP has already shown.

3.2. Evaluation of Reference Production Sites

The indicators have been evaluated for five production sites in countries of different development status. BMW in South Carolina in the United States and Skoda Auto in the Czech Republic form reference production sites in developed countries. Less developed countries were evaluated through Innoson Vehicle Manufacturing (IVM) in Nigeria, Tata Motors in India and VW in South Africa.

Due to missing data, it was not possible to evaluate every indicator for each reference case in the period before the start of production until today. A comparison of the results showed great strength of the automotive industry to positively influence the economic indicators. The share of the GDP by the automotive industry in India, Czech and South Africa is between 6,9 % and 9 % [24–26]. The GDP per capita increased in all cases. Fig. 2 shows the GDP per Capita exemplary for India and Maharashtra, the state where Tata Motors production location is. It visualizes the gap between Maharashtra and India, in the years where data was available.

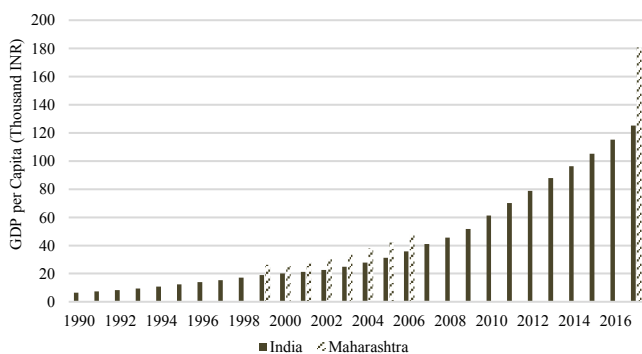


Fig. 2. GDP per Capita in India and Maharashtra. Source: WorldBank [27].

A growing local supplier network and rising competition ensures a high number of workplaces for locals. In the lesser developed countries, a significant rise of school enrolment and secondary school attainment can be observed. This complies with a descent of the illiteracy rate.

The effective battle against poverty in least developed countries was identified as a weakness. The positive economic influence of the automotive industry showed no improvement

of the share of people living in poverty, due to the small leverage of the domestic automotive industry. In Nigeria (IVM) and South Africa (VW), the share even increased. Automotive production companies appear to be great employers in least developed countries. As the wage is significantly higher than in other industries, such as agriculture. In South Africa the average wage at VW is more than seven times higher than the national minimum wage (Fig. 3).



Fig. 3. Minimum national wage and average wage in automotive production.

All reference production sites (as far as the available data shows) comply with the national regulation of working hours and paid vacation. Some cases even exceed the national regulations, since employees of all evaluated companies have health insurance and access to medical facilities (no data was available for IVM).

Overall, there is a great potential to influence a sustainable development of the regions through local production. The strength of a local production is the positive economic development, the improvement and support of the education in the surrounding area and the job creation through a local supplier network. An identified weakness is the unsuccessful battle against poverty. Potential for the employer lies in the creation of appropriate working conditions including a fair wage, fair working hours and a healthy and safe work environment. The long-term impact, as well as the social and economic sustainability of local production sites is significantly greater, the larger a company is and the longer it exists.

4. Application

Based on these findings of the reference productions, we derive recommendations for action for the ‘aCar mobility’ project which we introduce in the following section.

4.1. The ‘aCar mobility’ project

The ‘aCar mobility’ project was initiated to support rural regions in sub-Saharan Africa with a holistic concept: a vehicle which satisfies mobility needs and creates local value to support regions sustainably.

Thus, we developed the aCar – an all-wheel electric vehicle, designed to meet the basic needs for mobility (Fig. 4). We decided to use an electric drivetrain because of low total costs of ownership, independency from high costing fuel supply in rural regions [28 p.27].



Fig. 4. The aCar - an all-wheel electric vehicle for rural sub-Saharan Africa.

Furthermore, the drivetrain benefits from low maintenance costs and robust design counteracting the challenging supply of spare parts [29 p.24]. The aCar is driven by two 8 kW electric motors and has a battery with 20 kWh energy storage. This allows a maximum speed of 60 km/h and 80 km electric range. Due to its expanding functions the aCar can be used supporting field work, transporting goods and persons. Supplying the platform with 230 V fridges for medicine cooling, agricultural equipment or other electric devices can be operated. While developing the vehicle, we focused on sustainable value creation in sub-Saharan Africa. Thus, we designed the interior, exterior and frame to be manually manufactured. Components like the seats are designed for local production as well. Electric key components (battery, electric motor, harnesses, power electronics) and mechanical components with high developing expense (e.g. the axles, steering) will be supplied. Therefore, we want to develop recommendations to positively influence an electric vehicle production in the sub-Saharan region.

4.2. Recommendation for Sustainability for the Project

The sustainability evaluation of the reference production sites show that the automotive industry has great potential to influence regions sustainably. Based on the application examples, requirements were derived that are intended to promote sustainable development in the region. A sustainable development for a region is only noticeable over a longer production period. This requires long-term planning and a comprehensive analysis of the region. Local cooperation with government and research institutions enables a detailed market analysis and can strengthen successful product sales. The sustainability for the employee can be strengthened by the company through suitable protective measures for the prevention of accidents at work and the provision of medical care. For remuneration in least developed countries at least five times the local minimum wage is recommended in order to remain competitive as this minimum is oriented on the agricultural sector. Working hours should be regulated by law and should be 40-45 hours per week and include at least two weeks of leave per year. Positive development and promotion of the region can have a positive impact on education. Companies can actively support this through appropriate cooperation projects in local schools and thus increase the training from future employees. Smaller companies, such as the production of the aCar, can indirectly create additional jobs in the region by using local suppliers. In cooperation projects such as the aCar, expertise in vehicle assembly and management can

be used for efficient learning of local employees. The focus should be on profit-oriented work by the company in order to ensure the long-term existence of the company and to strengthen the region sustainably. The impact of local production on the region and society depends strongly on the size of the company. Smaller companies can create positive added value for employees, especially for stakeholders.

5. Conclusion

In this paper, we present a selection of indicators that assess vehicle production in terms of sustainability. The indicators are applied in studies by OEMs producing in developed and least-developed countries. On this basis we derived recommendations for our project, the ‘aCar mobility’ project. These can be generalized as following nine recommendations.

Long-term planning of locations: In terms of sustainability, location decisions for least developed countries are to be regarded as long-term commitments. Positive effects for the population increase with the duration of local production.

Cooperation with the local government and research institutions: The involvement of the local government is a success factor for the economic sustainability of companies. In the long term, cooperation with local educational institutions forms the basis for local R&D activities.

Focus on preventing industrial accidents in production: To protect employees, standards that apply in developed countries must also be applied to production in least developed countries.

Support for the medical care of workers: On the one hand, supporting employees in medical care ensures that they can work and, on the other hand, improves local health standards in terms of social sustainability.

Five times the local minimum wage as wage: A high income of employees promotes the local economy [30 p.58], enables them to have a good standard of living and prevents high employee turnover.

Working time of 40-45 hours per week and at least two weeks holidays: Adequate working and holiday times prevent illness, facilitate recreation and ensure a good standard of living.

Integration of local suppliers: Locally supplied components enable economical products, reduce transport emissions and create additional jobs in the region.

Active support for local educational institutions and training: This ensures the training of (future) employees. In addition, the region benefits from a well-trained workforce on the labour market.

Use of expertise: The use of available expertise such as managers from home production and local managers for questions on local competencies.

Profit-oriented work: Only a company that makes a profit is committed to a location in the long term.

Based on the evaluation of existing productions, the importance for companies, employees and the region to strive for a long-term and mutually beneficial relationship must be emphasized. This ensures social and economic sustainability irrespective of the size of the company and the region.

Contributions and Acknowledgements

Matthias Brönnner, as the contributing author initiated this paper and the concept. He conducted the research on production and the use case. Marie-Sophie Hagenauer wrote her master thesis on sustainability assessment and took over the selection of indicators and the evaluation of reference productions. Markus Lienkamp made an essential contribution to the conception of the research project. He revised the paper critically for important intellectual content. Mr. Lienkamp gave final approval of the version to be published and agrees to all aspects of the work. As a guarantor, he accepts responsibility for the overall integrity of the paper. This paper is a result of the ‘aCar mobility’ project. Further information can be found at <http://www.acar.tum.de/>. The research was conducted with basic research funds from the Institute of Automotive Technology, Technical University of Munich.

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