



Article

# Screening Indicators for the Sustainable Child Development Index (SCDI)

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**Abstract:** Since children are the key stakeholders supporting and being affected by sustainable development, the framework for the Sustainable Child Development Index (SCDI) was proposed. It addresses social, economic and environmental dimensions of sustainable development by considering seven relevant themes of child development, i.e., health, education, safety, economic status, relationship, environmental aspects and participation. However, an indicator set for initiating the SCDI is still missing. In this study, indicators for the themes, subthemes and criteria of SCDI are identified from literature and then analyzed regarding data availability. Sixty-six indicators with statistical data covering at least 100 countries are selected as the indicator set for the SCDI. The results indicate that data availability is best for indicators describing the themes of health and education, and worst for indicators addressing the themes of relationship and participation. Furthermore, 21 subthemes and 50 criteria described by indicators with limited data availability are identified for future indicator and data development. By providing an initial indicator set and screening the indicators with regard to data availability, the practicality of the SCDI framework is expected. Furthermore, the indicator set can serve as a potential indicator pool for other child and sustainable development related studies.

**Keywords:** sustainable development; sustainability assessment; Sustainable Child Development Index (SCDI); child development; indicator set; Sustainable Development Goals (SDGs)

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## 1. Introduction

Children are the stakeholders inheriting and shaping future society. The International Union for Conservation of Nature and Natural Resource [1] claimed that “we have not inherited the Earth from our parents, we have borrowed it from our children”. This claim emphasizes the important relationship between inter-generational equity, children and sustainable development (SD). Child development (CD) is affected by external circumstances, and children are more vulnerable to violence, diseases and environmental pollution than adults [2]. Furthermore, children’s basic rights such as to express their own opinions and to have access to education can be impeded by adults [2,3]. Disregarding and violating these basic rights can lead to irreversible and severe effects on CD and consequently on future society.

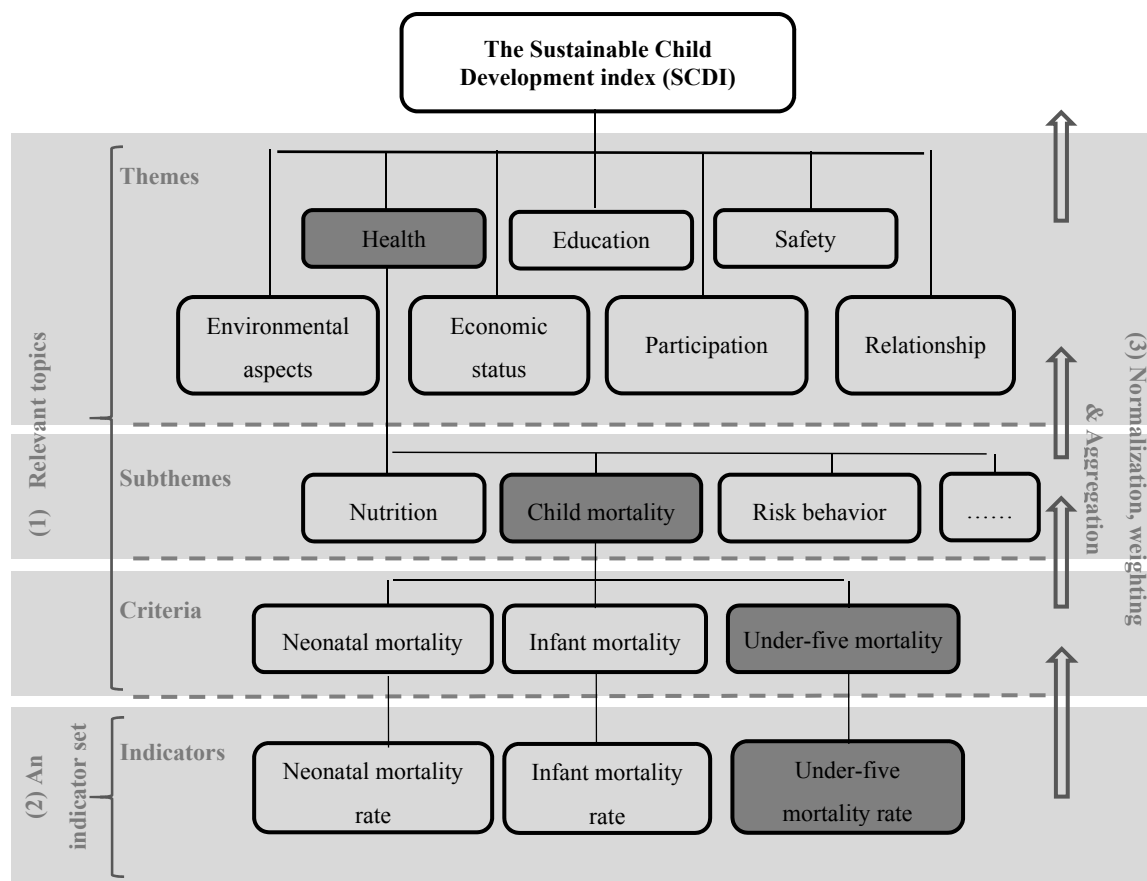
Many studies on CD are available and many schemes and indexes for assessing CD have been developed. The Handbook of Child Well-Being [4] indicates that the studies related to CD and well-being have undergone some relevant movements: multi-dimensional topics (for example, child rights) are increasingly addressed and new themes (for example, participation) are included. Accordingly, several indexes for CD were developed [5,6]. One famous example, the Child Development Index (CDI) [7,8], was proposed to evaluate countries’ performance on CD considering health, education and nutrition. It was designed to mirror the Human Development Index (HDI) [9]

with particular focus on children. Other government-supported institutions and NGOs proposed alternative indexes focusing more on well-being by considering additional topics, such as relationships with family, school and community, safety, or social engagement [10–14]. However, though these indexes are advanced compared to former ones focusing on single topics only, some limitations still remain. For instance, they do not address topics related to environmental aspects, such as water availability or resource consumption. Generally, a consistent classification of topics as well as a description of interdependencies between different topics is still a challenge.

### *1.1. The SCDI Framework and Potential Application*

To address some of those gaps, for example, lack of considering environmental aspects, inconsistent classification scheme, and missing description of interdependencies between topics, Chang et al. [15] proposed the Sustainable Child Development Index (SCDI) framework in the context of SD. This index is designed to be an aggregated score that presents countries' performance with regard to SD by considering relevant topics and indicators addressing environmental, economic and social dimensions. The performance can be treated as the potential towards SD by emphasizing intergenerational equality and the completed picture of SD. In addition, the SCDI can compare the performance for countries on CD and monitor the trends on improvements and declines of the performance for countries as well as specific topics by continuously updating the indicators over a defined time frame (e.g., on a four-year basis, such as done for CDI [7,8]). Therefore, the SCDI can support decision makers to formulate or adjust strategies on child as well as sustainable development policies, and, similar to HDI, is a communication tool in order to inform the condition on CD to policy makers, communities, academies, public and private organizations. As all indexes, the SCDI aims at summarizing a large amount of information from the included indicators to a manageable, meaningful message [16,17].

The SCDI framework considers seven themes, which, based on a literature review, were identified as relevant for CD: health, education, safety, economic status, relationship, and participation plus environmental aspects. Each theme is specified by subthemes and criteria. Figure 1 displays the overall structure of the SCDI. For example, the theme health includes 17 subthemes like child mortality, nutrition and risk behavior. Subthemes are further described by criteria, which are measured by indicators. The subtheme child mortality contains three criteria, such as neonatal-, infant-, and under-five mortality. The criterion under-five mortality is assessed by the indicator under-five mortality rate. As an index for SD, the SCDI also reflects the Sustainable Development Goals (SDGs). SDGs were adopted in 2015 by 193 countries and target at holistically tackling development needs, eradicating poverty in all its forms, improving human rights and gender equality, and considering SD in environmental, social and economic dimensions [18,19]. There are some links between SDGs and the identified relevant topics in the SCDI framework [15,18]. For example, the goal "ensure healthy lives and promote well-being for all" is associated with the subthemes child mortality, mental health, maternal mortality, immunization, etc.; the goal "ensure access to affordable, reliable, sustainable and modern energy for all" links to the subtheme renewable energy consumption; and the goal "ensure inclusive and quality education for all and promote lifelong learning" relates to the subthemes gender equality, access to all levels of education, and provision for vocational training.



**Figure 1.** The structure of the SCDI (exemplary criteria and indicator are presented for the subtheme child mortality, adapted from Chang et al. [15]).

The SCDI framework provides a consistent classification scheme for topics relevant for CD and includes environmental aspects, which was not yet considered in previous studies on CD but relevant in SDGs. Furthermore, the subthemes and criteria are allocated to the outcome and the contextual level. The outcome level considers topics reflecting the status of CD, such as the subtheme school attainment. The contextual level considers topics, such as the subtheme parents' educational qualification, which can potentially affect the outcomes. For instance, growing up in a relatively low parents' educational qualification family may, but does not inevitably, lead to negative effects on children's school attainment. This indicates the topics on contextual level are connected with the topics on outcome level, but should not be considered as direct measures of the outcome. Thus, this two-level differentiation reveals the interdependency between subthemes and criteria. This is crucial to avoid overstressing or neglecting the outcomes and the influences of contexts on CD [15].

This SCDI framework was the first step for developing a SCDI (illustrated in the first three blocks in Figure 1) and was discussed in detail in Chang et al. [15]. The second step—the main task of this paper—is to provide an indicator set for constructing the SCDI to measure CD on country level and to screen the data availability for indicators for the identified topics. It is illustrated in the fourth block in Figure 1 and further explained in Section 1.2. The development of normalization and aggregation approaches needed for determining the SCDI is a topic for the future research (see also discussion). The SCDI is planned to be designed as the arithmetic average of normalized indicators for each of the relevant themes. By normalization, indicator scores measured on different scales are adjusted to a common scale, i.e., the units of indicators are removed. Therefore, an aggregation of different indicators to their corresponding subthemes and thus themes is possible. Finally, arithmetic average scores of the themes are calculated for summarizing the relative CD performance of countries.

## 1.2. Research Objective

Currently, many indicators related to CD are available in the literature and considered in existing indexes. However, according to Fernandes et al. [20], who reviewed the leading research on the measurement of CD and well-being through indexes, common classification of indicators used in the indexes is lacking. One indicator can be classified into different topics. For instance, the school enrolment indicators were assigned to address education in many indexes [13,14,21], but were allocated to participation in some other indexes [22,23]. Consequently, allocating an indicator to a specific topic is not always straightforward. That indicates a robust classification system needs to be developed. Moreover, some studies did not clarify the data availability of indicators, or did not specify the indicators needed for measuring the topics [10,24–28]. Consequently, such indexes may not be applied in practice, as data for one or more indicators are simply not available on country level. To foster the implementation of the SCDI, developing an indicator set based on sufficiently available data is necessary.

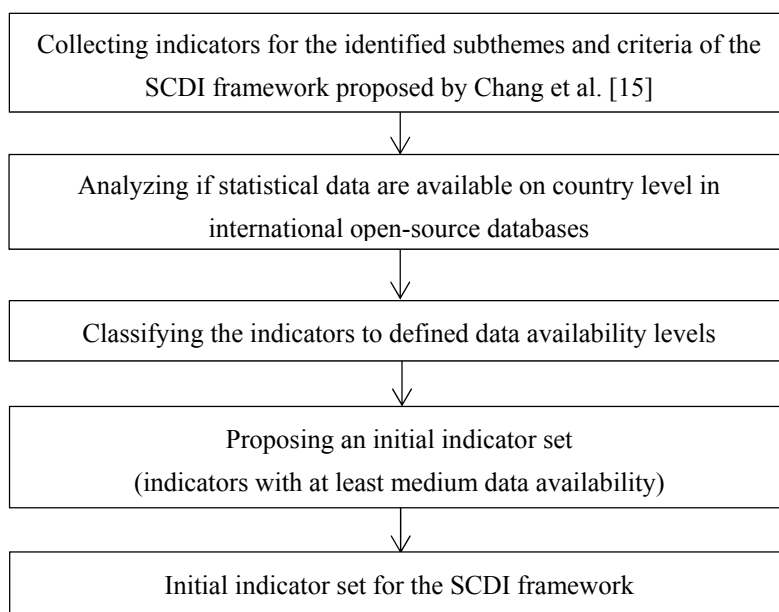
Hence, the objective of this study is to transparently provide an initial indicator set for developing the SCDI and to screen the indicators for the identified topics of the SCDI framework with regard to data availability. Such an analysis of the indicators is needed because the SCDI is designed to assess countries' performance on CD in the context of SD and the assessment can be only implemented if data are available. Indicators that already have available data are proposed as an initial indicator set to put the SCDI in practice. The indicator set is the basis for further development of the SCDI, facilitating a quantitative assessment of the relevant topics of sustainable child development and thus the implementation of the SCDI. In addition, according to the analysis of the indicators, the topics described by indicators with limited data are underlined for future indicator and data development. Moreover, the indicator set can serve as a basic indicator pool to support decision makers and researchers for formulating or adjusting development indexes related to child as well as sustainable development policies and studies.

The succeeding sections present the research materials and methods (Section 2), results, including the provision of the indicator set and the analysis of the indicators for the topics with regard to data availability (Section 3), followed by research discussion (Section 4) and conclusion (Section 5).

## 2. Materials and Methods

For identifying an initial indicator set for the SCDI framework, a review and analysis of indicators were conducted. The approach started with collecting indicators that reflected the identified subthemes and criteria of the SCDI framework. It was checked if statistical data were available on country level. Then, the data availability for the indicator was classified in different data availability levels—depending on the number of countries for which data were provided. Through this indicator analysis, indicators with sufficient data availability (at least medium data availability, further explained in the following paragraphs) were selected as an initial indicator set. The subthemes and criteria described by indicators with limited data availability on country level are identified. The result was an initial indicator set, which now allows assessing CD in the context of SD on country level. An overview of the research approach is shown in Figure 2. A detailed description is provided in the following.

Indicators for the defined subthemes and criteria of the SCDI framework were collected from seven peer-reviewed publications [13,28–33], three book sections [22–24], five studies from Non-Governmental Organizations (NGOs) specialized in CD research [8,10,14,27,34], as well as 14 reports from government-supported institutes [11,12,21,26,35–44] and 11 international databases established by government-supported institutions [45–55]. For example, the reports and database of United Nations Office on Drugs and Crime (UNODC) [50] and the United Nations Children's Fund (UNICEF) [45] were used as the key references of the theme safety. By considering studies and databases from an academic, organizational and governmental background, a comprehensive set of indicators can be provided.



**Figure 2.** Research approach of the study.

After completing the indicator collection, it was checked if statistical data were available for the indicators on country level in the international, accessible databases or studies that are highly involved in development research, such as United Nations Children’s Fund (UNICEF), World Health Organization (WHO) and World Bank. In this study, these international databases and reports are considered as the fundamental data sources because they frequently update statistics and clearly provide the data sources and calculation methods. As the statistical data were taken from these renowned references, a high data quality is assumed and thus the data are suitable for investigating data availability further. We established a scheme to describe different data availability levels and to define a level considered as sufficient for initiating the SCDI. For the scheme, the number of countries considered in the UNICEF database (195) was taken as a reference: if one indicator had statistical data for all 195 countries, the indicator was classified into the top data availability level. In total, seven data availability levels were defined: top, very high, high, medium, low, very low and no available statistical data (on country level). The defined data availability levels are listed in Table 1. For example, an indicator with statistical data covering 160 countries was not classified to the top and very high data availability level, but included in the high data availability level. If an indicator has no available statistical data at country level (e.g., on regional level) from international databases, then the indicator is assigned to the no available statistical data level.

**Table 1.** Scheme of data availability levels of indicators.

	Data Availability Level						No Available Statistical Data
	Top	Very High	High	Medium	Low	Very Low	
Numbers of covered country	195	$195 > N \geq 175$	$175 > N \geq 150$	$150 > N \geq 100$	$100 > N \geq 50$	$50 > N \geq 1$	0

The data availability level scheme provided an overview on the data availability of the indicators identified for the subthemes and criteria of the SCDI framework, and indicated which subthemes and criteria could currently be assessed in all countries or in just a few. These results were used for proposing an initial indicator set for the SCDI framework. In concrete terms, we proposed to consider those indicators, which were allocated to at least the medium data availability level

(from top to medium data availability levels). It implied that data for the indicators are available at least in 100 countries, representing more than 50% of the countries listed in the UNICEF database. The subthemes and criteria described by indicators with low and very low data availability, and no available statistical data (hereafter defined as limited data availability) are concerned as the topics that need more development of indicator and data (e.g., data collection and methodological improvement for indicators) before being considered in the SCDI.

### 3. Results

In total, 154 indicators were collected for the subthemes and criteria of the SCDI. For 139 indicators, statistical data were found on country level in international open-source databases. For the other 15 indicators, statistical data were not found on country level (e.g., regional level) or were not accessible in international open-source databases. A detailed list of all the 139 indicators identified for the topics as well as all the corresponding data coverage (and data sources) are provided in the Supplementary Materials, Table S1. The following sections provide the results of the analysis of the data availability of these 154 indicators. Based on the results, an initial indicator set for the SCDI and the topics concerned with limited data availability are stated. An initial indicator set is proposed (in Section 3.1). A detailed description of the findings of the data availability analysis is given in Section 3.2.

#### 3.1. Selection of the Initial Indicator Set

According to the results of the indicator collection, Table 2 summarizes the accumulative numbers of indicators, criteria, subthemes, and themes structured in different data availability levels. The accumulative numbers of indicators and topics for a specific data availability level cover the indicators and topics considered in the better data availability level(s). For example, the at least high data availability level includes the indicators from top, very high, to high data availability level. Table 2 shows that only a few (seven) indicators have top data availability; that is, the data are available for 195 countries. It also shows that only a few topics are covered by these seven indicators with top data availability. A trade-off between the data availability for the indicators for the SCDI framework and its comprehensiveness (regarding the considered topics) is revealed in Table 2. If all themes and subthemes identified in the SCDI framework should be considered in developing a future SCDI, the data availability would be low, meaning that data of many indicators measured in a SCDI would only be available for few countries. On the other hand, if good data availability would be a criterion for selecting indicators considered in the SCDI, only few indicators would be used and thus only few subthemes and themes would be addressed. For example, if the criterion for including an indicator in a SCDI is, that data should be available in all countries (the top data availability level), the SCDI would only consider two themes (health and safety), three subthemes, child mortality, immunization coverage, and violence and crime, and the respective seven criteria (neonatal mortality, infant mortality, under-five mortality, Measles containing vaccine (MCV) immunization, Diphtheria tetanus toxoid and pertussis (DTP3) immunization, Polio (Pol3) immunization, and criminal victimization).

To develop an initial indicator set for the SCDI framework, a compromise between data availability and coverage of topics is needed. It is proposed to consider indicators with at least medium data availability for the proposed indicator set; that is, data cover at least 100 countries. In addition, it means that more than 50% of all subthemes and criteria identified in the SCDI framework are included. For example, 29 out of 50 subthemes, and 59 out of 109 criteria are taken into account. Furthermore, all seven themes are considered. As a result, 66 indicators are proposed for the initial indicator set of SCDI. This indicator set is presented in Table 3.

Moreover, the identified relevant topics in the SCDI are associated with some SDGs. The corresponding SDGs and SDG targets for the initial SCDI indicator set are listed in the Supplementary Materials, Table S2. Moreover, the overlap between the initial SCDI indicator set and the SDG indicator set is checked and presented in Table S2 as well. The results show that 39 out of the 66 SCDI indicators (59%) are also considered as SDG indicators. That indicates the SCDI

indicator set has compatibility with the SDG indicator set. Nonetheless, the results do not imply that the indicators of the initial SCDI indicator set which are not suggested as SDG indicators have low relevance of SD. These SCDI indicators respond to SDGs and SDG targets. Besides, the SDG indicators are classified into three tiers with regard to data availability and the level of methodological development [56]. This classification can also serve as a reference to support the data availability we analyzed for the initial SCDI indicator set. In the SDG framework, Tier I considers the indicators that have clear established methodologies, and data regularly produced by countries. Tier II includes the indicators that have clear established methodologies, but data are not regularly produced by countries. Tier III addresses the indicators that have no firmly established methodologies. Among the 39 indicators (both considered in the initial SCDI indicator set and the SDG indicator set), 30 (77%) are assigned to Tier I, and the other nine are categorized to Tier II. None of the indicators of the initial indicator set are classified as Tier III indicators. That shows the indicator set provides indicators that have both good data availability and sound methodological development. As revealed in the SDG indicator classification, further research for indicator and data improvement is needed for those indicators without regularly updated data at country level and firmly established methodologies. Few collected SCDI indicators (e.g., Number of people covered by health insurance or a public health system per 1000 population) were found as Tier III indicators due to the lack of statistical data at country level. This outcome points out that the ongoing SDG indicator development with regard to Tier III indicators could also be beneficial for the future SCDI indicator development.

**Table 2.** Accumulative numbers of covered indicators and topics in different data availability levels.

Data Availability Level	Covered Indicators	Covered Topics
Top data availability	7	2 themes, 3 subthemes, 7 criteria
At least very high data availability	34	5 themes, 19 subthemes, 29 criteria
At least high data availability	44	5 themes, 22 subthemes, 41 criteria
At least medium data availability	66	7 themes, 29 subthemes, 59 criteria
At least low data availability	84	7 themes, 33 subthemes, 70 criteria
At least very low data availability	139	7 themes, 46 subthemes, 98 criteria
No statistical data at country level	154	7 themes, 50 subthemes, 109 criteria

**Table 3.** Initial indicator set based on at least medium data availability.

Theme	Subtheme	Criteria	Indicator	Data Availability		Source
				Covered Countries	Level	
Health	Nutrition	Low birth weight	Percentage of infants born with low birth weight (<2500 g)	187	Very high	UNICEF Childinfo [45]
		Overweight and obesity	Overweight (including obesity, %)	146	Medium	
		Breast feeding	Exclusive breastfeeding < six months (%)	167	High	
		Underweight	Underweight (moderate and severe, %)	148	Medium	
		Wasting	Children under five below minus two standard deviations from median weight-for-height (%)	147	Medium	
		Stunting	Children under five below minus two standard deviations from median height-for-age (%)	147	Medium	
	Child mortality	Infant mortality	Infant mortality rate (probability of dying between birth and age one per 1000 live births)	195	Top	
		Under-five mortality	Under-five mortality rate (probability of dying by age five per 1000 live births)	195	Top	
		Neonatal mortality	Neonatal mortality rate (during the first 28 completed days, per 1000 live births)	195	Top	
	Oral health	Dental treatments	DMFT (decayed, missing or filled teeth) among 12-year-olds	180	Very high	Malmö University Oral Health Database [46]
	Mental health	Suicide	Suicide rate, 15–29 year-olds, per 100,000	171	Very high	WHO [40]
	Hazardous pollutant	Household and ambient air pollution	Mortality rate attributed to household and ambient air pollution (per 100,000 population)	172	High	WHO [47]
		PM <sub>2.5</sub> air pollution	PM <sub>2.5</sub> air pollution, population exposed to levels exceeding WHO guideline value (% of total)	187	Very high	
	Immunization coverage	Measles containing vaccine (MCV) immunization	Measles (MCV) immunization coverage among one-year-olds (%)	195	Top	UNICEF [45]
		Diphtheria tetanus toxoid and pertussis (DTP3) immunization	Diphtheria tetanus toxoid and pertussis (DTP3) immunization coverage among one-year-olds (%)	195	Top	
		Polio (Pol3) immunization	Polio (Pol3) immunization coverage among one-year-olds (%)	195	Top	
Hepatitis B (HepB3) immunization		Hepatitis B (HepB3) immunization coverage among one-year-olds (%)	185	Very high		
Bacillus Calmette-Guérin (BCG) immunization		Bacille Calmette-Guérin (vaccine against tuberculosis) immunization coverage among one-year-olds (%)	164	High		



Table 3. Cont.

Theme	Subtheme	Criteria	Indicator	Data Availability		Source	
				Covered Countries	Level		
Health	Risk behavior	Alcohol use	Percentage of 15–19 years old heavy episodic drinkers	189	Very high	WHO; World Bank [47,52]	
		Adolescent fertility	Adolescent fertility rate (per 1000 girls aged 15–19 years)	184	Very high		
	Physical behavior	Physical activity	Comparable estimates of prevalence of insufficient physical activity (adolescents 11–17 years)	120	Medium	WHO [42]	
	Maternal health	Antenatal care	Percentage of women aged 15–49 years attended at least once during pregnancy by skilled health personnel (doctor, nurse or midwife)	149	Medium	UNICEF Childinfo [45]	
		Maternal mortality	Maternal mortality ratio (MMR, maternal deaths per 100,000 live births)	183	Very high		
		Skilled attendant at birth	Percentage of births attended by skilled health personnel (doctor, nurse or midwife)	168	High		
	Health expenditure	Public health expenditure	Public health expenditure as % of total health expenditure	190	Very high	WHO; World Bank [47,52]	
	Water and sanitation	Access to improved sanitation facilities	Improved sanitation facilities (% of population with access)	191	Very high	UNICEF; WHO; World Bank [45,47,52]	
		Access to improved drinking-water sources	Population using improved drinking-water sources (%)	193	Very high		
	HIV	HIV prevalence among youth	Estimated percentage of young men and women (aged 15–24) living with HIV	128	Medium	UNICEF [57,58]	
	Education	School attainment	Overall literacy	Youth literacy rate, population 1–24 years, both sexes (%)	151	High	UNESCO [48]
			Repetition	Repetition rate in primary education (all grades), both sexes (%)	165	High	
Completion of education		Primary school completion	Gross graduation ratio from primary education, both sexes	107	Medium		
		Secondary school completion	Gross graduation ratio from lower secondary education, both sexes (%)	114	Medium		
		Tertiary school completion	Gross graduation ratio from first degree programmes (ISCED 6 and 7) in tertiary education, both sexes (%)	120	Medium		
Attendance of education		Enrolment in primary school	Gross enrolment ratio, primary, both sexes (%)	191	Very high		
		Enrolment in secondary school	Gross enrolment ratio, secondary, both sexes (%)	188	Very high		

Table 3. Cont.

Theme	Subtheme	Criteria	Indicator	Data Availability		Source	
				Covered Countries	Level		
Education	Attendance of education	Enrolment in tertiary school	Gross enrolment ratio, tertiary, both sexes (%)	175	Very high	UNESCO [48]	
	Early childhood education	Enrolment of kindergarten	Gross enrolment ratio, pre-primary, both sexes (%)	187	Very high		
	Government support on education	Public expenditure on education	Government expenditure on education as % of GDP	179	Very high		
	Gender equality in enrolment			Gross enrolment ratio, pre-primary, gender parity index (GPI)	176		Very high
				Gross enrolment ratio, primary, gender parity index (GPI)	190		Very high
				Gross enrolment ratio, secondary, gender parity index (GPI)	187		Very high
				Gross enrolment ratio, tertiary, gender parity index (GPI)	177		Very high
	Gender equality in graduation			Gross graduation ratio from primary education, gender parity index (GPI)	134		Medium
				Gross graduation ratio from lower secondary education, gender parity index (GPI)	134		Medium
				Gross graduation ratio from first degree programmes (ISCED 6 and 7) in tertiary education, gender parity index (GPI)	137		Medium
	Gender equality in youth literacy			Youth literacy rate, population 1–24 years, gender parity index (GPI)	152		High
Safety	Violence and crime	Criminal victimization	Juveniles held in prisons, penal institutions or correctional institutions	108	Medium		
			Juveniles brought into formal contact with the police and/or criminal justice system, all crimes	108	Medium		
			Intentional homicide count and rate per 100,000 population	195	Top		
			Assault and major assault rates in different countries (police recorded assaults/100,000 population)	128	Medium		
			Sexual violence against children	Total sexual offences against children at the national level, police-recorded offences, rate per 100,000 children aged 17 or under	102	Medium	

Table 3. Cont.

Theme	Subtheme	Criteria	Indicator	Data Availability		Source
				Covered Countries	Level	
Safety	Birth registration	Registration of newborns	Birth registration rate	166	High	UNICEF [45]
	Child labor	Children involved in child labor	Percentage of children five-14 years old involved in child labor	112	Medium	
	Child marriage	Children married or in union	Percentage of women aged 20–24 years who were first married or in union before ages 18	123	Medium	
	Demographic structure	Sex ratio	Sex ratio at birth	191	Very high	CIA [53]
Economic status	Housing quality	Electricity coverage	Access to electricity (% of population)	191	Very high	World Bank [52]
	Macroeconomic situation	Overall unemployment	Unemployment, total (% of total labor force) (modeled ILO estimate)	170	High	
		Youth unemployment	Youth unemployment rate (% of total labor force ages 15–24)	170	High	
	Macroeconomic situation	Income equality at societal level	Income Gini coefficient	156	High	
		National income	GNI per capita, Purchasing power parity (current international \$)	183	Very high	
	National debts	Public debt as percentage of GDP	179	Very high	CIA [53]	
Relationship	Community relationship	Social capital	Social Capital Ranking	140	Medium	Legatum Institute [44]
Participation	Social media connection	Internet access in home	Proportion of households with internet access at home	138	Medium	ITU [54]
		Access to public media	Proportion of households with computer	126	Medium	
Environmental aspects	Freshwater vulnerability	Risk of depleting freshwater resources	Water depletion index (WDI)	192	Very high	Berger et al. [33]
	Renewable energy consumption	Consumption of renewable energy	Renewable energy consumption (% of total final energy consumption)	180	Very high	World Bank [52]

### 3.2. Analysis of Indicators for the SCDI

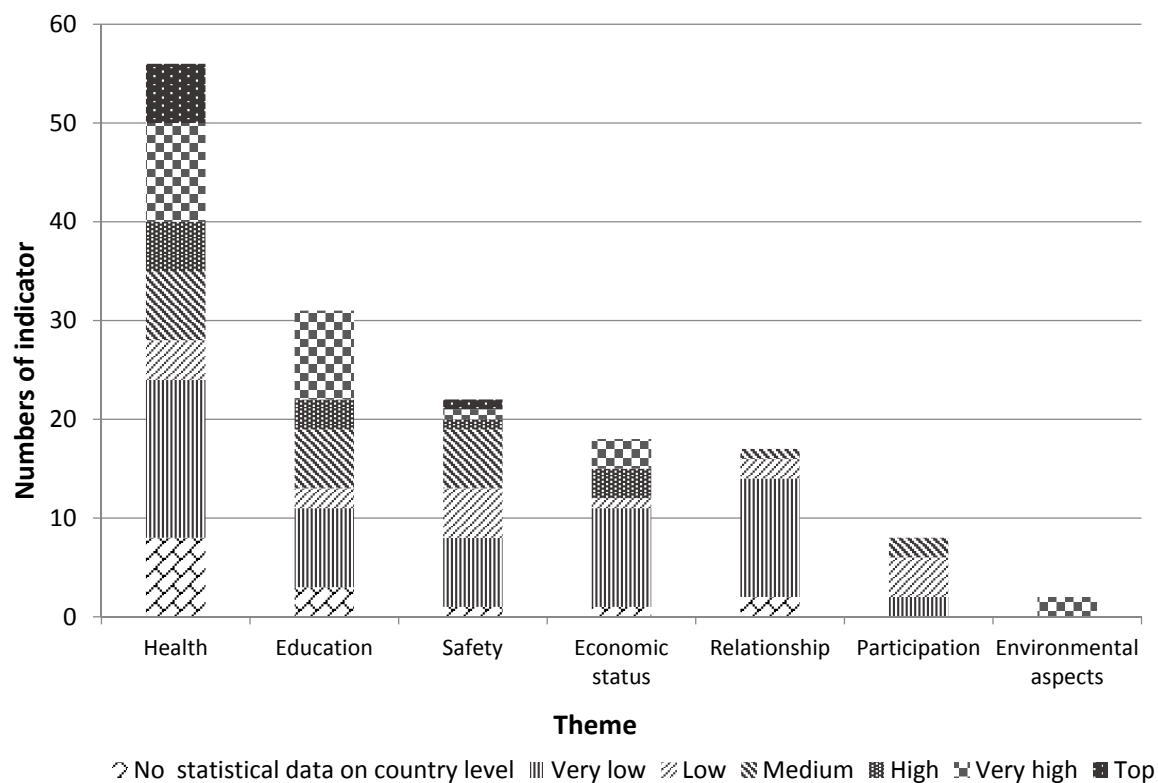
The key messages gained from the analysis of indicators for the SCDI are summarized in the following bullet points, and are then explained in detail.

- The data availability of indicators differs among the different topics, for example data availability for the theme health is high, but for the theme relationship is low.
- The share of indicators differs for the different topics of the SCDI framework, for instance most indicators are available for the theme health.

It is shown that data availability varies significantly for the topics of the SCDI framework. Figure 3 shows the results of the analysis of data availability for the 154 indicators collected for the seven themes of the SCDI framework, such as health, safety, relationship. It is displayed that only for six indicators in the theme health and one indicator in the theme safety, data are available for all countries, that is, on top data availability level. In general, health and education are the themes that have most indicators with better data availability. For example, Figure 3 displays that for the themes health and education, there are large shares of the indicators from top to medium data availability levels. On the other hand, the indicators for the themes relationship and participation are mainly considered in the medium, low, very low data availability levels. This finding indicates that the indicators of the themes relationship and participation have a worse data availability to evaluate CD. Thus, the development of data collection of theme relationship and participation shall be noticed and further improved. Besides, some indicators of the theme health, economic status and relationship show worse data availability because their associated data source are especially limited to certain countries, for example Organization for Economic Co-operation and Development (OCED) and European countries [12,38,41,49,51]. The themes health, education, relationship include many indicators that have no statistical data at country level. For example, the indicators that assess chronic diseases, disability and illicit drug use have statistical data only on regional level from international databases. In addition, some indicators were conceptually proposed for the SCDI framework for addressing subjective-evaluated topics, e.g., reading pleasure and satisfaction to family, without collecting data in practice. A detailed list of numbers of indicators for different themes in different data availability levels is shown in the Supplementary Materials, Table S3.

It is also shown that most indicators are available for the theme health. The theme health covers over one third of the collected indicators (37%). The key reason may be that health was the main theme in early CD related studies, having more indicators developed than other themes. That indicates the indicators are concentrated on the theme health. While measuring CD, it shall be noticed not to overuse the indicators of the theme health. Education is another theme of large share of the indicators (20%). The themes economic status (12%), relationship (11%) and participation (5%) obtain minor share of indicators. This reveals a need for further indicator development of the three themes. Besides, currently, only two indicators are selected for the theme environment aspects. As the theme was newly proposed in Chang et al. [15] for assessing CD in the context of SD, more indicators associated to resource accessibility are needed for a more comprehensive coverage of environmental aspects in the SCDI framework.

Besides, the theme health holds the largest share of the initial indicator set (43%) followed by the theme education (26%). Other themes, for example relationship, participation, and environmental aspects, individually represent 1–3% of the indicator set. It indicates that though the identified seven themes are covered in an initial indicator set, the portion of themes relationship, participation, and environmental aspects is relatively small. The minor share of these themes shall be considered when implementing and interpreting the SCDI. Besides, the result also responds to the fact that health and education are the themes that have the most indicators with sufficient data availability; that is, at least medium data availability (also shown in Figure 3).



**Figure 3.** Numbers of the indicators in different data availability levels, by themes of the SCDI framework

As described in Section 2, the indicators for the SCDI topics were screened with regard to data availability. An overview of the themes and subthemes of the SCDI framework including their data availability is provided in Figure 4. In Figure 4, bold wording and bullet correspondingly indicate the themes and subthemes. Superscripts note the highest data availability level that indicators have in each subtheme. T, VH, H, M, L, VL, and N corresponding to top, very high, high, medium, low, very low data availability level, and no statistical data on country level, respectively. The detailed lists of corresponding criteria of the subthemes are provided in the Supplementary Materials, Table S4. The subthemes and criteria which are described by indicators with limited data availability are identified and recommended to conduct further indicator and data development, e.g., data collection and methodological improvement of indicators. Four subthemes and 11 criteria were recognized as the topics described by indicators lacking statistical data available on country level from international databases. The four subthemes are chronic diseases, disability, other participation in education, as well as debt and financial difficulty. The 11 criteria are depression, emotional and behavior difficulty, maternal smoking, health insurance coverage, family smoking, illicit drug use, parents reading to children, reading pleasure, extracurricular subjects, satisfaction of family, and satisfaction of community. Additionally, 17 subthemes and 39 criteria only have indicators assigned to low and very low data availability levels. These subthemes and criteria are also provided in Table S1. In total, 21 subthemes (marked with superscripts L, VL, and N in Figure 4) and 50 criteria described by indicators with limited data availability are considered in the SCDI framework, but for now are not included in the initial indicator set in order to facilitate implementation of the SCDI. The challenge of data availability shall be noticed and addressed by indicator and data development measures, such as methodology development and data collection.

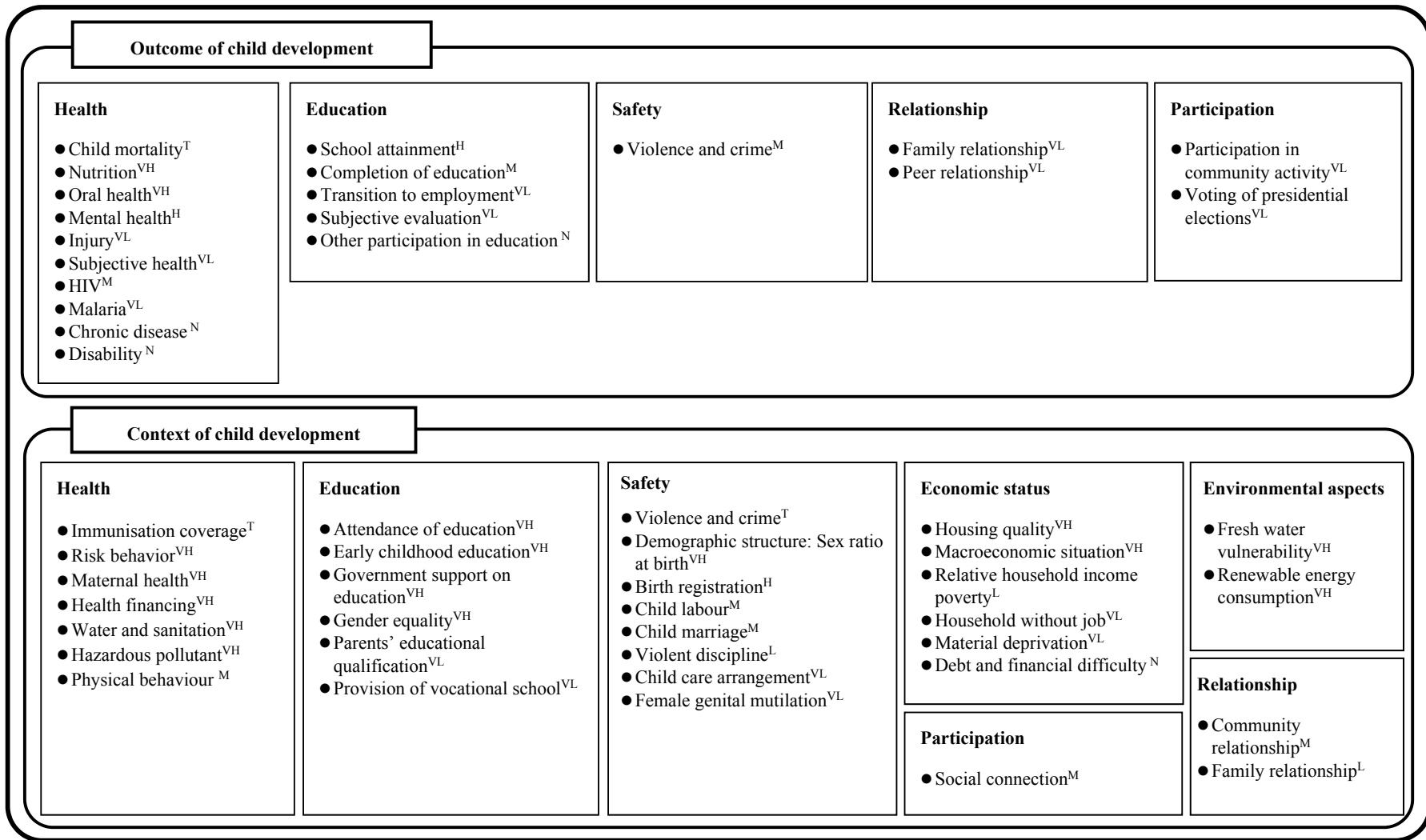


Figure 4. The overall framework of Sustainable Child Development Index (adapted from Chang et al. [15]).

To be noticed, addressing economic status as a purely contextual theme is a modification of the SCDI framework proposed by Chang et al. [15]. The indicators for the theme economic status refer to the background of economy in which children grow up and live with. For instance, housing quality, macroeconomic situation, and household income poverty are the factors to influence development of children, but not the direct performance acted by children. Thus, the theme economic status shall be allocated only on contextual level. The subthemes and criteria of the theme economic status separated on the two levels in the original SCDI framework are put together on contextual level. To sum up, the SCDI framework contains seven themes, 50 subthemes, and 109 criteria. It includes five themes (health, educational, safety, relationship, and participation) addressing the outcome level and seven themes (the previous five themes, economic status, and environment aspects) addressing the contextual level (see Figure 4).

#### 4. Discussion

This study provides an initial indicator set for the SCDI and identifies the SCDI topics described by indicators with limited data availability. This contribution can serve as the basis for further developing the SCDI in the context of SD to allow a comparison of countries in terms of their relative performance, and for fostering indicator and data development for the topics with limited data availability.

Nevertheless, some research challenges remain, such as the limited consideration of indicators in specific themes, such as environmental aspects and participation, and inconsistent reference years of statistical data for the indicators. For instance, among all 154 identified indicators, there are only eight for the theme participation, and two for the theme environmental aspects. The limited inclusion of indicators may lead to insufficient and biased evaluation of sustainable child development. Since participation is a relatively new topic in evaluation of sustainable child development, existing indicators with available data are few. The theme environment aspects was newly proposed in Chang et al. [15] for assessing CD in the context of SD. Freshwater vulnerability and renewable energy consumption were selected as the two relevant subthemes for the theme environmental aspects in the SCDI framework; nevertheless, other potential topics (such as soil quality and erosion) that are specifically related to resource accessibility and intergenerational equality usually have limited statistical data on country level. The databases need to be developed and more indicators addressing resource accessibility need to be considered in the SCDI framework for a more comprehensive coverage in order to emphasize intergenerational equality.

Besides, reference years of statistical data for the indicators are not identical. Statistical data of indicators for most of the subthemes (e.g., child mortality and attendance of education) are updated annually. On the other hand, indicators for few subthemes (e.g., renewable energy consumption and mental health) are updated on a four-year basis. Considering the indicators with lower update frequency, the SCDI is thus suggested being updated on a four-year basis (i.e., over a longer period than one year). This suggested updating period is also in line with the CDI. As the SCDI is designed for assessing and monitoring the improvements or declines of CD for countries, this arrangement for updating frequency could be also reasonable as longer time frames may be needed to make the trend of the country's performance regarding sustainable child development visible.

Currently, there are no commonly used or widely suggested methods to normalize and aggregate multi-dimensional indicators for computing one index. In order to construct a SCDI, defining proper normalization and aggregation methods as well as weighting choices is the next step for this research (also see Figure 1). Sensitivity analysis will also be conducted to test the robustness of a SCDI.

Moreover, the indicators were collected based on the identified relevant subthemes and criteria summarized in Chang et al. [15]. Thus, the SCDI framework and indicators will have to be continuously revised and updated when additional literature and statistical data with regard to sustainable child development become available. In accordance with the indicator analysis considering data availability, the subthemes (e.g., family relationship and parents' educational qualification) that have indicators only with limited data availability (see Figure 4) have priority in indicator and data development.

The ongoing SDG indicator development is also beneficial and can be taken as reference for supporting SCDI indicator development.

In addition, the SCDI and the proposed initial indicator set will be tested in exemplary case studies to investigate the validity and potential to be integrated into existing sustainability assessment approaches. Since the indicator set is proposed considering good data availability and reliable data, it can serve as a supplementary indicator pool to support researchers for developing or adjusting development indicators and indexes related to child as well as sustainable development policies and studies (e.g., the HDI families and CDI).

## 5. Conclusions

In total, 154 indicators are identified for the topics of the Sustainable Child Development Index (SCDI) framework with statistical data on country level and then analyzed regarding data availability. Among the collected indicators, 66 indicators with statistical data covering at least 100 countries are proposed as an initial indicator set. The indicator analysis also shows that the theme health has the largest share of collected indicators and obtains many indicators with good data availability. On the other hand, most of the indicators of the themes relationship and participation have limited data availability. Moreover, 21 subthemes and 50 criteria described by indicators with limited data availability at this point of time are underlined to call on indicator and data development.

The contribution of this paper is the provision of an indicator set for initiating the SCDI that can clearly measure the relevant topics of sustainable child development and has available statistical data to support a quantitative assessment. Therefore, the practicality of the SCDI framework is expected. Such a detailed analysis is required to transparently describe the development of the SCDI. In addition, the individual indicators of the set can also serve as a basic indicator pool for being applied and adapted in other CD and SD related studies. It is expected to support decision makers to draw up strategies on child as well as sustainable development policies, and serve as a communication tool to stakeholders. The next steps will focus on the development of calculation methods such as normalization and aggregation for the SCDI.

**Supplementary Materials:** The following are available online at [www.mdpi.com/2071-1050/9/4/518/s1](http://www.mdpi.com/2071-1050/9/4/518/s1), Table S1: 139 indicators collected for Sustainability Child Development Index, Table S2: The relation of the initial indicator set of the SCDI to the SDG indicator development, Table S3: Numbers of indicators of the themes in different data availability levels, Table S4: Subthemes and criteria of the SCDI framework.

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