

BMJ Open Modelling the cost of community interventions to reduce child mortality in South Africa using the Lives Saved Tool (LiST)

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ABSTRACT

Objective To estimate the costs and impact on reducing child mortality of scaling up interventions that can be delivered by community health workers at community level from a provider's perspective.

Setting In this study, we used the Lives Saved Tool (LiST), a module in the spectrum software. Within the spectrum software, LiST interacts with other modules, the AIDS Impact Module, Family Planning Module and Demography Projections Module (Dem Proj), to model the impact of more than 60 interventions that affect cause-specific mortality.

Participants DemProj Based on National South African Data.

Interventions A total of nine interventions namely, breastfeeding promotion, complementary feeding, vitamin supplementation, hand washing with soap, hygienic disposal of children's stools, oral rehydration solution, oral antibiotics for the treatment of pneumonia, therapeutic feeding for wasting and treatment for moderate malnutrition.

Primary and secondary outcome measures Reducing child mortality.

Results A total of 9 interventions can prevent 8891 deaths by 2030. Hand washing with soap (21%) accounts for the highest number of deaths prevented, followed by therapeutic feeding (19%) and oral rehydration therapy (16%). The top 5 interventions account for 77% of all deaths prevented. At scale, an estimated cost of US\$169.5 million (US\$3 per capita) per year will be required in community health worker costs.

Conclusion The use of community health workers offers enormous opportunities for saving lives. These programmes require appropriate financial investments. Findings from this study show what can be achieved if concerted effort is channelled towards the identified set of life-saving interventions.

BACKGROUND

More than 40 000 children under the age of 5 years die every year in South Africa from preventable causes, mainly diarrhoea and pneumonia.^{1 2} Progress has been made in the last decade, with child and infant mortality reducing significantly. Under-5 mortality

Strengths and limitations of this study

- The Lives Saved Tool is a widely used robust priority setting tool that has been extensively reviewed and used to influence policy in low and middle-income countries.
- The model used in this analysis offers an alternative to measured impact of community health interventions, which can be costly undertakings.
- One limitation of this analysis is that interventions for saving the lives of children are included as standalone interventions and not packages of care, thus the overall impact is potentially overestimated.
- While intervention costs are provided, this study is not a full economic evaluation, which only considers costs of labour, drugs and supplies associated with the essential interventions.

reduced from 56 deaths per 1000 live births in 2009 to 39/1000 in 2014 and infant mortality from 39/1000 (2009) to 28/1000 (2014).³ This progress has occurred at a time during which there has been rapid scale up of prevention of mother to child transmission of HIV and improvement in the coverage of other essential child health interventions including immunisations and increased access to water and sanitation. However, this has not been sufficient to reach the country's millennium development goals of reducing infant and under-5 mortality rates by two-thirds in 2015.

As the country looks to a new set of sustainable development goals beyond 2015, there is a need to focus on essential interventions that have been shown to be effective in improving child health. Recent analyses in South Africa identified a set of priority interventions that can have an impact on stillbirths,⁴ maternal, newborn and child mortality.⁵ Interventions such as family planning can avert more than 7000 newborn and child lives, at a cost of US\$7 per year per user of family planning.⁶ Investing an additional US\$9 to US\$18 per capita in 13

interventions to prevent diarrhoea can save more than 3000 additional child lives every year.⁷ Scaling up these essential maternal and child health interventions will require concerted effort and a strengthening of the health system, a process which has already been initiated by the government.

In 2011, South Africa initiated its primary healthcare (PHC) re-engineering programme in a bid to improve health systems performance and access to health. PHC re-engineering is aimed at positioning PHC as the mainstay of the health sector in responding to the quadruple burden of disease (HIV/tuberculosis (TB), maternal and child health, non-communicable burden of disease and violence and injury). South Africa's approach to PHC re-engineering relies heavily on PHC outreach teams which include professional nurses, health promotion practitioners and community health workers (CHWs).

Global evidence has shown that CHWs can effectively deliver interventions in primary healthcare including nutrition, maternal and child health, malaria control, TB control, HIV/AIDS prevention and control, mental health and non-communicable disease.⁸⁻¹³ A Cochrane review of CHW interventions identified 107 randomised controlled trials which showed promising benefits, compared with usual facility care in increasing immunisation uptake in children, improving breastfeeding rates until 6 months, reducing neonatal mortality and improving pulmonary TB care rates.¹⁴ The review also reported that CHWs interventions reduce child morbidity and mortality, maternal mortality and increase the likelihood of caregivers seeking care for children who are ill.

There is a small but growing evidence base of cost effectiveness studies of CHW interventions in low and middle-income countries.^{15 16} More recently, there is evidence of the cost-effectiveness of CHW interventions in reducing malaria and asthma,¹⁷ mortality of neonates and children,¹⁷ malnutrition¹⁷ and increasing exclusive breastfeeding^{18 19} and increasing uptake of home-based HIV testing.²⁰ However, there is still a need to provide more information on the cost and impact of community health worker interventions to aid priority setting and decision-making for the improvement of child health.

In this paper, we use the Lives Saved Tool (LiST), a widely used priority setting tool, to estimate the costs of scaling up interventions that can be delivered by CHWs at community level.²¹ LiST has been previously used in South Africa to identify the essential interventions that can save the lives of children, together with the costs of these interventions.^{5-7 22} It has also been used in other low and middle-income countries to assess the cost-effectiveness of community health worker programmes.¹⁵ Our paper describes the methods used in LiST to estimate the cost of deploying CHWs and the overall impact that the selected interventions can have on reducing child mortality. This information is necessary for South Africa, as it pursues the goal of Universal Health Care.

METHODS

This analysis used the LiST, a module in the Spectrum software, which models the impact of increased coverage of health interventions on maternal, newborn and child mortality.²¹ Within the Spectrum software, LiST interacts with other modules, the AIDS Impact Module, Family Planning Module and Demography Projections Module (DemProj) to model the impact of more than 60 interventions that affect cause-specific mortality.²³ LiST is a deterministic mathematical model that compares the effect of various interventions on population level risk factors, as well as stillbirths and maternal, newborn and child deaths.^{21 24} The primary model inputs are coverage of interventions and the outputs are changes in risk factors (such as stunting rates) and cause-specific mortality. Interventions included in the model can have an impact on single or multiple causes of death and risk factors, with outcomes changing based on the level of intervention coverage. Increasing the level of coverage of one or more interventions can thus lead to a reduction in associated risk factors or cause-specific mortality.

Intervention impact on mortality can be direct or indirect (through the reduction of risk factors). The direct impact of each of these interventions is modelled by multiplying its effectiveness estimate with the level of coverage, assuming all other interventions are kept constant. For example, an intervention with an effect estimate of 30% can avert 30% of the associated cause-specific deaths if coverage for that intervention is 100%.

The modelling methods used in LiST have been used in several studies.^{25 26} In South Africa, LiST has been used to identify the potential cost and impact of scaling up interventions on stillbirths,⁴ diarrhoea²⁷ and maternal, newborn and child mortality.^{28 29} In our model, we use LiST to model the impact of interventions to reduce child mortality and then estimate the resources required for the portion of interventions that are delivered at community level.³⁰

Nine interventions (described in [table 1](#)) available in LiST that can be delivered at community level and have been shown to effectively impact child mortality are used in the model. The focus on these interventions was because they can be delivered by CHWs at community level. The baseline coverage of all interventions included in LiST was maintained, and only scaled up for the nine community interventions, from baseline levels (2015) to full coverage at 99% (2030). Increases in coverage were assumed to be gradual and interpolated over the 15-year period.

The baseline mortality rates used were 41 deaths per 1000 live births for under-5 children and 13/1000 for neonates.³¹ The causes of newborn and child mortality³² are given in [figure 1](#). The relationship between the nine interventions scaled up in the model and the causes of death are shown in [table 1](#). The interventions are mainly focused on diarrhoea.

[Table 2](#) shows the per cent delivery of each intervention at different levels in the base and target years. Taking promotion of breast feeding for example, the table shows that in the base year, the coverage of this intervention is

**Table 1** Description of interventions

Intervention	Description of the intervention	Cause of death affected	Effect estimate
1. Breastfeeding promotion	Breastfeeding promotion can be either one on-one or group meetings. It is assumed that children 1–5 months of age who are exclusively breast fed do not need breastfeeding promotion.		
2. Complementary feeding	This intervention only benefits children 6–24 months of age who are living on more than a dollar a day. This can be delivered in the home, community or clinic, by health professionals or health volunteers. It includes the assumption that breast feeding should be continued for children 6–24 months of age, (but does not affect breastfeeding rates). The intervention includes education on the proper foods to prepare as well as appropriate hygiene for food preparation.		
3. Vitamin A supplementation	This intervention covers the percent of children 6–59 months receiving full coverage with Vitamin A. Full coverage of Vitamin A supplementation is considered to be two doses of Vitamin A in the past year. It is assumed that all children in a country with Vitamin A deficiency are in need of Vitamin A for prevention.	Diarrhoea	47%
4. Hand washing with soap	Appropriate hand washing is defined as washing hands with soap, ash or other materials and using adequate water, after handling faeces and before preparing food.	Diarrhoea	48%
5. Hygienic disposal of children's stools	Per cent of children's stools that are disposed of safely and contained. Stools are considered to be contained if: (1) the child always uses a toilet/latrine, (2) the faeces are thrown in the toilet or latrine or (3) the faeces are buried in the yard.	Diarrhoea	20%
6. Oral rehydration solution (ORS)	Per cent of children with diarrhoea given ORS from sachets. This includes sachets or premixed solutions of ORS.	Diarrhoea	93%
7. Oral antibiotics for the treatment of pneumonia	Proportion of children 1–59 months with suspected pneumonia or acute respiratory infections (ARI) treated with antibiotics	Pneumonia	70%
8. Therapeutic feeding for wasting	Percent of wasted children receiving therapeutic feeding. Therapeutic feeding is outpatient treatment for severely wasted children (<-3Z) including supplementation with food (such as PlumpyNut) and maternal education. Therapeutic feeding is only applied to the per cent of children severely wasted. It shifts children from the severely wasted category to moderately (-3to-2Z) and mildly (-2 to -1Z) wasted categories.	Other causes	20%
9. Treatment for moderate malnutrition	Percent of moderately wasted children (-3 to -2Z) receiving outpatient treatment including supplementation with food (such as PlumpyNut) and maternal education. Treatment for MAM shifts children from the moderately wasted category into the mildly wasted category (-2 to -1Z).	Other causes	20%

25% and will be scaled up to 99% in the target year 2030. In the base year, breastfeeding promotion is delivered 50% at community level and 25% each at outreach and clinic levels. While we assumed that overall intervention coverage for the nine interventions increased, the level assigned to each delivery channel remained the same. Setting the per cent delivery is essential to determining the resource requirements at the different levels. It is also important to note that LiST models the overall impact of each intervention, and intervention impact does not take into consideration the model of delivery (whether delivered at community or facility level).

Estimation of costs and resource requirements

Costs were modelled from a provider perspective, using the costing module in LiST. The module uses an

ingredients approach to costing, based on four components: personnel and labour; drugs and supplies; other recurrent costs and capital costs. In the analysis for costs of community health workers, the items included are personnel and labour and drugs and supplies. Staff remuneration is based on current salary structures of health workers in South Africa, with an allowance made for annual cost of living adjustments at 5.6% per annum.³³ The unit costs of drugs and supplies are based on international drug prices from Unicef and the Management for Sciences Health International Drug Price Indicator.^{34 35}

The primary personnel input in LiST are staff time, which is then converted to annual staff costs. Thus, LiST cannot for example calculate the number of personnel required for a particular intervention but can be used to

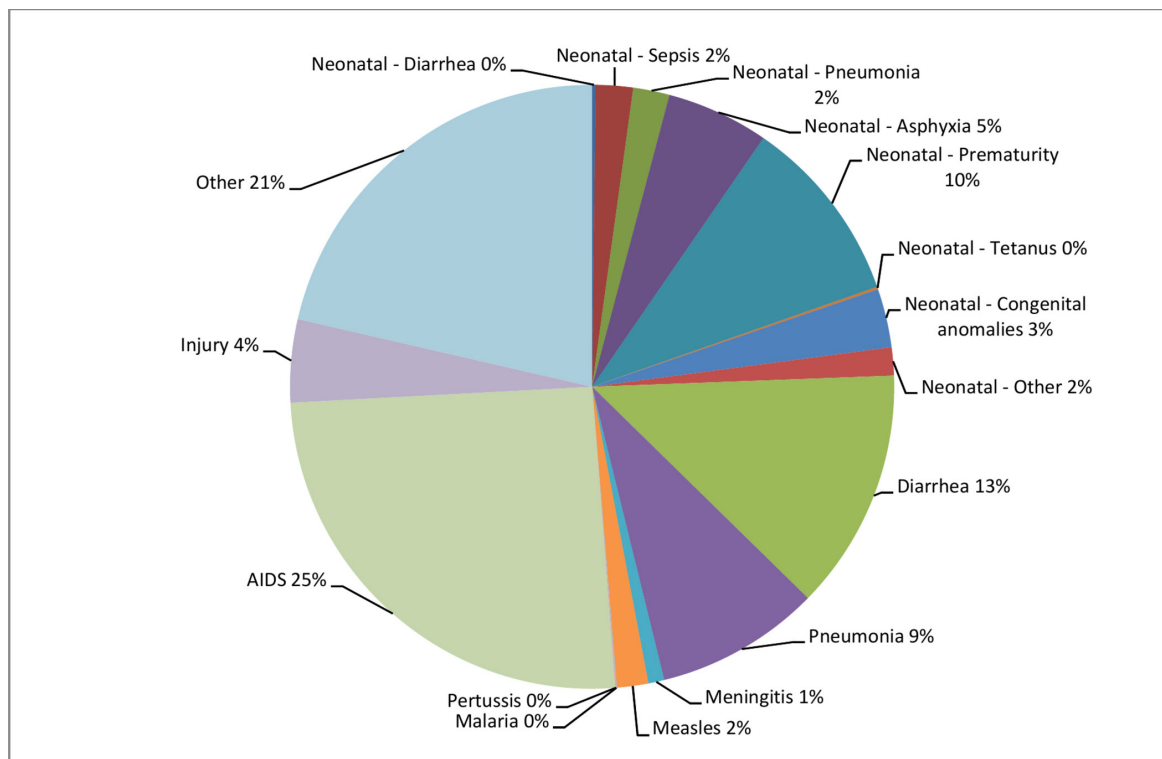


Figure 1 Causes of death in children under 5 years used in LiST (adapted from MRC, 2010). LiST, Lives Saved Tool.

estimate the effort required to scale up an intervention (in terms of staff time).

Costs were estimated in South African Rand (ZAR) and converted to US\$, at an average exchange rate of US\$1 to ZAR13 in 2015. All costs were adjusted to 2015 using the Consumer Price Index.

RESULTS

The model estimates a total fertility rate of 2.4, approximately 1.4 million pregnancies and 1.2 million births in 2015. The projected number of pregnancies and births in 2030 reduces to 1.2 million and 1 million, respectively.

Table 2 Per cent intervention coverage and delivery at different levels

Interventions	Coverage		Delivery channels					
	Baseline year	Target year	Community		Outreach		Clinic	
			Baseline year	Target year	Baseline year	Target year	Baseline year	Target year
Promotion of breast feeding	25	99	50	50	25	25	25	25
Complementary feeding—education only	10	99	50	50	0	0	50	50
Vitamin A supplementation	50	99	50	50	50	50	0	0
Hand washing with soap	17	99	100	100	0	0	0	0
Hygienic disposal of children's stools	40.5	99	100	100	0	0	0	0
Oral rehydration solution	50	99	50	50	0	0	50	50
Oral antibiotics: case management of pneumonia in children	73.2	99	50	50	0	0	50	50
Therapeutic feeding—for severe wasting	45	99	20	20	0	0	80	80
Treatment for moderate acute malnutrition	10	99	20	20	0	0	80	80

**Table 3** Total number of deaths (all interventions)

Age group	Baseline	Scale up to 99%
	2015	2030
<1 month	13 356	12 435
1–59 months	26 857	17 569
Total (0–59 months)	40 214	30 004

Overall intervention impact on child mortality

Table 3 provides the estimated number of deaths at baseline in 2015 and after full scale in 2030. The number of deaths reduces from approximately 40 214 in 2015 to 30 004 in 2030. Thus, 10 210 deaths are prevented in this period, out of which a total of 8322 deaths prevented are attributed to the nine community interventions that were scaled up in this analysis (**table 4**). Hand washing with soap (22%) accounts for the highest number of deaths prevented, followed by therapeutic feeding (21%) and oral rehydrating

solution (ORS; 17%). The top five interventions account for 82% of all deaths prevented.

Estimations of resource requirements

The total costs of all the interventions used in the analysis (including costs of all delivery channels, ie, community, outreach and health facility) are estimated to be US\$74 million (US\$1 per capita) in 2015 (**table 5**). This is expected to rise to US\$565 million (US\$10 per capita) if interventions are scaled up to 99% coverage in 2030. In comparison, the costs of the community component are US\$19.8 million (US\$0.37 per capita) in 2015 and US\$169.5 million in 2030. The difference in the total and community costs shows the impact that a higher cadre of staff would have in relation to costs. The required number of workers was calculated by converting the personnel time estimated in LiST.

Table 4 Additional deaths prevented by nine community interventions, 2030

Intervention	Number of deaths prevented	% deaths prevented
Hand washing with soap	1828	22%
Therapeutic feeding—for severe wasting	1730	21%
Oral rehydration solution	1426	17%
Oral antibiotics: case management of pneumonia in children	1025	12%
Appropriate complementary feeding	822	10%
Hygienic disposal of children's stools	543	7%
Vitamin A supplementation	394	5%
Promotion of breast feeding	319	4%
Treatment for moderate acute malnutrition	235	3%
Total	8322	100%

This table provides the additional number of deaths prevented attributable to the nine community interventions scaled up to full coverage.

Table 5 Costs and resource requirements (US\$)

Interventions	2015		2030	
	Total	Community	Total	Community
Promotion of breast feeding	1 123 509	561 754	10 038 173	5 019 086
Complementary feeding (education only)	1 149 336	122 720	25 679 246	2 741 903
Vitamin A supplementation	549 421	71 866	2 394 368	2 805 52
Hand washing with soap	2 375 468	2 375 468	37 526 223	37 526 223
Hygienic disposal of children's stools	5 659 204	5 659 204	37 526 223	37 526 223
Oral rehydration solution	19 270 311	2 575 185	34 500 213	4 086 458
Oral antibiotics: case management of pneumonia in children	3 298 578	378 909	10 045 584	1 106 962
Therapeutic feeding—for severe wasting	28 213 620	5 621 596	135 840 638	27 062 171
Treatment for moderate acute malnutrition	12 549 660	2 500 542	271 778 014	54 143 689
Total	74 189 107	19 867 246	565 328 681	169 493 266
Personnel time (hours)				
Community health workers		3 339 796		11 140 869

Total costs include costs of all delivery channels (community, outreach and health facility).



Considering only the baseline costs at community level, hygienic disposal of stools is estimated to have the highest cost of labour at US\$5.7million. Therapeutic feeding for wasting comes in second at US\$5.6million and oral rehydration solution has the third highest cost of US\$2.6million. When interventions are at scale in 2030, the highest costs are projected for treatment of moderate acute malnutrition (US\$54million), hand washing with soap and disposal of stools (US\$37million each) and therapeutic feeding for wasting (US\$37million).

Approximately 3.3million hours of work per year at the community level are required at baseline, compared with 11.1million hours when interventions are fully scaled up. Based on a full-time equivalent working a 6-hour day for a full year, we the required community health workforce to deliver the interventions used in this model will be about 3000 at baseline and 11 000 at full coverage.

DISCUSSION

This analysis used the LiST, a widely used priority setting tool to estimate the cost and impact of interventions delivered at community level to prevent child mortality. The results show that scaling up nine interventions that are conducted at both community and facility level can prevent an additional 8300 lives per year. The top five interventions: hand washing with soap, therapeutic feeding for wasting, ORS, oral antibiotics for pneumonia and appropriate complementary feeding, account for 82% of all additional deaths prevented, that is, implementing only these five interventions at scale can prevent an additional 6800 child deaths per year.

This is an important finding as it has implications for considerations when choosing the most effective interventions to meet the new sustainable development goals for child health. Considering that not all interventions can be fully implemented given budgetary constraints, focusing on the identified five most effective interventions can contribute to achieving the desired results. Other considerations such as cost implications have to be made when choosing which interventions to implement.

In 2011, it was estimated that there were more than 72 000 community health workers in South Africa, delivering various interventions.³⁶ In our projection, we estimated that approximately 11 000 community health workers would be required to deliver the nine interventions used in this analysis at scale. This could be an underestimate, and we have no basis for comparisons with other studies. Caution should be taken when considering our estimate, because it is based on a projected baseline level of coverage for the modelled interventions, level of effort required to deliver the interventions and an annual salary, all of which could be different in other models.

The labour costs of community health workers have been provided in this analysis. We show that at scale, an estimated cost of US\$169.5million (US\$3 per capita) per year will be required. The top five most effective interventions are also the most costly, probably because they

are more personnel intense, with a lot of time spent on extensive demonstrations. Provision of oral antibiotics for example requires diagnosis, treatment and follow-up. It is important to note though, that the overall cost of an intervention will be influenced by among other things, the level of coverage, with more effort required to scale up low coverage interventions.

The costs provided in this analysis are likely an underestimate of the true costs of deploying community health workers, which have been shown to be substantial. Equipment costs have not been included nor have the usually large administrative costs also been considered. Future research should look into providing the overall cost structure as this has important implications for how health workers are deployed and accounted for. Future analyses should take these costs into consideration, as it has been shown that they can contribute to the overall cost-effectiveness of interventions.^{37 38}

This analysis also had a limitation in that it did not consider the interventions included as part of a package of interventions that can be delivered by a single health worker. The interventions are standalone. While looking at the individual impact of interventions is useful and can help to understand the value of each intervention, this does not truly reflect the way most interventions are implemented in reality, as packages. It is therefore possible that we potentially overestimated the overall health impact of the interventions included in this analysis. Further, we also could have overestimated the costs, since savings tend to be higher when interventions are packaged than when they standalone. However, other considerations should also be made on how packaged community health services would work and on whether a single health worker loaded with several different messages to deliver to a home will be as effective as one who is focused on one specific message, for example, breastfeeding promotion.

The interventions included in this analysis have been shown to be effective in reducing child mortality. Extensive reviews of the literature were undertaken to gather information on intervention effectiveness by the Child Health Epidemiology Reference Group.³⁹ In this analysis, we have shown the potential impact that these interventions can have on reducing child mortality in South Africa. However, cognisance should be taken of the challenges that could be faced with deploying CHWs in the South African context. Healthcare in South Africa remains mainly facility based, and provided by professional health workers, while CHWs mainly facilitate health promotion. Therefore, an intervention such as case management of pneumonia, which requires some level of diagnostic ability as implemented in other settings,^{40 41} might not work for CHWs in South Africa. A lot of effort will have to be placed in training CHWs and redefining their roles. Such efforts would incur costs that have not been considered in this study. The usefulness of our study is that it puts forward evidence that can be used to argue for the expansion of the roles of South African CHWs.



We focused on only nine interventions that can be delivered at community level, by maintaining constant coverage of other child health interventions. This may not be very realistic since in the real world, coverage of the other interventions is likely to increase, resulting in a lower burden of under-5 mortality by 2030. It is therefore possible that we have overestimated the total number of deaths prevented.

Furthermore, the LiST model assumes that the health system interventions are delivered at uniformly high quality. This is unlikely given drug shortages, healthcare worker attitudes and institutional challenges. Significantly more resources are probably required to address such issues.

CONCLUSION

South Africa has made significant progress with regard to reducing child mortality although this was not sufficient to meet the MDG deadline in 2015. As the new sustainable development goals materialise, and South Africa heads towards Universal Health Care, understanding what the best package is and how it can be delivered is essential. To do this, there is a need to consider essential and effective interventions that will have the most impact on saving the lives of South African children. In this paper, we have provided information on the cost and impact of nine effective interventions that can be delivered at community level. We show that implementing just five of these interventions can prevent as many as 6800 additional deaths of children every year. The community health worker costs of implementing the nine interventions do not seem to be substantial, at R41 per capita. This seems to be well within the scope and affordability of the South African health budget.

Contributors LN and KH conceived the study and participated in the design. LN and LC conducted the analysis of the data. All authors participated in interpretation of data, drafting and critical revision of the manuscript and approved the final version.

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Data sharing statement The model data can be made available to interested researchers. No additional data available.

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