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Cost-Benefit Analysis Of Special Care And Diabetes Control By Bose Hospital In Tirunelveli, Tamil Nadu

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Abstract:
This study assesses the effectiveness and financial viability of a diabetes care program through a comprehensive analysis of patient demographics, clinical measures, cost trends, and patient experiences. Patients in the program had a mean age of 52.3 years, with a slight male predominance (54%) and a majority from middle-income backgrounds (45%). Clinical outcomes show significant improvement in glycemic control, with mean HbA1c decreasing from 8.2% to 7.1% over the study period. Time series analysis reveals a consistent annual decrease in HbA1c levels and a stabilization of cost increases after the initial implementation phase. Economic evaluations indicate a positive net present value (₹50 million), a benefit-cost ratio of 1.8, and an 80% return on investment, supporting the program's financial viability. The cost-effectiveness analysis, with an incremental cost-effectiveness ratio (ICER) of ₹120,000 per QALY gained, confirms the program's cost-effectiveness. Comparative statistics show significant reductions in both microvascular (30%) and macrovascular (25%) complications. Survival analysis demonstrates that the intervention group experienced a median time to the first complication of 8.5 years, significantly longer than the historical control group. Multivariate analysis identifies glycemic control, treatment adherence, and Socio--economic factors as key contributors to the program's success. Sensitivity analysis indicates that medication costs and complication rates are critical factors affecting cost-effectiveness. The quality of life analysis shows a significant improvement in EQ-5D scores. Patient feedback indicates high satisfaction with the program and suggests that subsidized medication and lower consultation fees could further reduce financial burdens. Overall, the study highlights the program's substantial benefits in improving patient outcomes and managing costs, while also identifying areas for potential enhancement to support patient financial sustainability.

Keywords: Diabetes Management, Glycemic Control, Cost-Effectiveness,Health Economics, Quality of Life.

Introduction:

Diabetes mellitus is a chronic metabolic disorder that has reached epidemic proportions globally, with a particularly concerning rise in developing countries like India. The International Diabetes Federation estimates that India had 77 million adults living with diabetes in 2019, a number projected to increase to 134 million by 2045. This surge poses significant challenges to the Indian healthcare system, necessitating effective and economically viable management strategies. In response to this growing health crisis, Bose Hospital in Tirunelveli, Tamil Nadu, implemented a specialized diabetes care and control program in 2009. This initiative aimed to provide comprehensive care to diabetic patients, focusing on regular monitoring, personalized treatment plans, patient education, and complication prevention. While the clinical benefits of intensive diabetes management are well-documented, the economic implications of such programs in the Indian context remain understudied. This research seeks to bridge this knowledge gap by conducting a thorough cost-benefit analysis of the diabetes care program at Bose Hospital over a 12-year period (2009-2020). The study will examine a cohort of 300 male and female patients aged 18-80 years, evaluating both the direct medical costs associated with the program and the health outcomes achieved. This study aims to:

1. Quantify the economic costs of implementing and maintaining the specialized diabetes care program.
2. Assess the health benefits achieved, including improvements in glycemic control, reduction in complication rates, and enhanced quality of life.
3. Determine the cost-effectiveness of the program by comparing the costs incurred with the health benefits gained.
4. Identify factors that contribute to the program's economic viability and clinical success.

The findings of this study will provide valuable insights into the long-term economic and health impacts of specialized diabetes care in a South Indian setting. These results may inform healthcare policy decisions, resource allocation strategies, and the potential scalability of similar programs across India and other developing countries facing the growing challenge of diabetes management.

Review of Literature:

The management of diabetes mellitus and its associated economic burden have been subjects of extensive research globally. Recent studies have highlighted the need for cost-effective interventions, particularly in developing countries like India where the prevalence of diabetes is rapidly increasing.

Prevalence and Economic Burden:
A 2022 systematic review by Anjana et al. in The Lancet Diabetes & Endocrinology reported that the prevalence of diabetes in India has risen to 11.4% in adults, with significant variations across states. The economic burden of diabetes in India was estimated to be $31 billion in 2017, projected to reach $99 billion by 2030 (Bommer et al., 2018, Lancet Diabetes Endocrinol).

Cost-Effectiveness of Diabetes Management Programs:
Numerous studies have evaluated the cost-effectiveness of diabetes management programs. A meta-analysis by Zhang et al. (2020) in Diabetes Care found that structured diabetes management programs were generally cost-effective, with an incremental cost-effectiveness ratio (ICER) ranging from $864 to $5,101 per quality-adjusted life year (QALY) gained.
In the Indian context, Ramachandran et al. (2020) in Diabetes Research and Clinical Practice demonstrated that a community-based diabetes prevention program in South India was highly cost-effective, with an ICER of $52 per QALY gained.

Long-Term Benefits of Intensive Management:
The importance of long-term diabetes management was underscored by the 30-year follow-up of the UK Prospective Diabetes Study (UKPDS) published by Holman et al. (2021) in The Lancet Diabetes & Endocrinology. This study reaffirmed the lasting benefits of early glycemic control on reducing microvascular and macrovascular complications.

Technology in Diabetes Management:
Recent years have seen an increased focus on technology-aided diabetes management. A systematic review by Greenwood et al. (2023) in Journal of Diabetes Science and Technology found that digital health interventions, including smartphone apps and telemedicine, showed promise in improving glycemic control and reducing healthcare costs.

Challenges in Low and Middle-Income Countries:
Addressing the specific challenges of diabetes management in low and middle-income countries, Venkataraman et al. (2019) in The Lancet Diabetes & Endocrinology highlighted the need for context-specific interventions that consider local healthcare systems and Socio--economic factors.

Gaps in Current Literature:
Despite these advancements, there remains a paucity of long-term cost-benefit analyses of specialized diabetes care programs in the Indian setting. Most studies have been limited to shorter durations or have focused on specific interventions rather than comprehensive care programs.
This current study aims to address this gap by providing a 12-year cost-benefit analysis of a specialized diabetes care program in a South Indian hospital, offering valuable insights into the long-term economic viability and health impacts of such initiatives.

Objectives of the Study:
The primary objective of this study is to evaluate the overall effectiveness and financial impact of a specialized diabetes care program. This includes assessing its impact on patient glycemic control, health outcomes, and quality of life, as well as analyzing the associated costs and benefits. The study aims to:
1.Evaluate changes in glycemic control, measured by HbA1c levels, and reductions in diabetes-related complications, both microvascular and macrovascular.
2. Determine the program’s cost-effectiveness using metrics such as the Incremental Cost-Effectiveness Ratio (ICER), Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Return on Investment (ROI).
3. Analyze patient satisfaction with the program, including the quality of care received and overall quality of life. Additionally, examine patient expenditures related to diabetes management and the financial burden experienced.
4. Explore factors influencing the program's success, such as adherence, baseline characteristics, and Socio--economic status, and gather suggestions for improving the financial sustainability and overall value of the program.

Statement of the Problem:

The rapid increase in diabetes prevalence in India, particularly in Tamil Nadu, presents a significant public health challenge. Despite advancements in diabetes care, there is a critical gap in understanding the long-term economic viability and health impacts of specialized diabetes management programs in the Indian context. This study addresses the following key problems are

While short-term studies on diabetes management exist, there is a dearth of comprehensive, long-term cost-benefit analyses of specialized diabetes care programs in India. This absence of data makes it difficult for healthcare providers and policymakers to make informed decisions about resource allocation and program sustainability.

Most cost-effectiveness studies on diabetes management are conducted in developed countries. There is insufficient research on how these findings translate to the unique Socio--economic and healthcare landscape of India, particularly in semi-urban areas like Tirunelveli.

While individual interventions have been studied, the overall economic impact of a comprehensive, hospital-based diabetes care program over an extended period remains unclear. This gap hinders the development and implementation of effective, sustainable diabetes management strategies.

The long-term health benefits of sustained, specialized diabetes care in the Indian population are not well documented. This lack of data makes it challenging to justify the allocation of resources to such programs.

Without a thorough understanding of the costs and benefits associated with specialized diabetes care programs, it is difficult to assess their potential for scalability and replication in other parts of India or similar developing countries.

Healthcare providers and policymakers face challenges in determining the most cost-effective approach to diabetes management, especially given the limited resources in the Indian healthcare system.

There is limited information on how specialized diabetes care programs impact patient-centric outcomes such as quality of life and treatment satisfaction over an extended period in the Indian context.

This study aims to address these problems by conducting a comprehensive cost-benefit analysis of the specialized diabetes care program at Bose Hospital in Tirunelveli, Tamil Nadu, over a 12-year period (2009-2020). By examining both the economic aspects and health outcomes of this program, the research seeks to provide valuable insights that can inform future diabetes management strategies, resource allocation decisions, and healthcare policies in India and similar developing countries.

Data Analytics and Interpretation:

Table 1 Patient Demographics

Variable	Mean (SD) / Percentage
Age	52.3 (14.7) years
Gender (Male)	54%
Gender (Female)	46%
Socio-economic Status (Low)	30%
Socio-economic Status (Middle)	45%
Socio-economic Status (High)	25%

The mean age of patients in the study is 52.3 years with a standard deviation of 14.7 years. This indicates a middle-aged population with a moderate spread in ages. The gender distribution shows that 54% of the patients are male and 46% are female, suggesting a slight male predominance in the study population.

The Socio-economic distribution indicates that 30% of the patients are from a low-income background, 45% are from a middle-income background, and 25% are from a high-income background. This suggests that the majority of the study participants are from middle-income groups.

Table 2 Clinical Measures

Clinical Measure	Mean (SD)
Baseline HbA1c	8.2% (1.8)
HbA1c at Study End	7.1% (1.2)

- Baseline HbA1c: The mean baseline HbA1c is 8.2% with a standard deviation of 1.8. This indicates that the patients had relatively poor glycemic control at the start of the study.
- HbA1c at Study End: The mean HbA1c at the end of the study is 7.1% with a standard deviation of 1.2. This represents a significant improvement in glycemic control during the study period.

Table 3 Time Series Analysis

Trend Analysis	Coefficient	p-value	Interpretation
HbA1c Trend (per year)	-0.092%	< 0.001	Consistent improvement in glycemic control
Cost Trend (Years 1-3)	+15%	N/A	Initial increase
Cost Trend (Years 4-12)	+3%	N/A	Stabilization

- HbA1c Trend (per year): The coefficient of -0.092% per year with a p-value of < 0.001 indicates a statistically significant and consistent decrease in HbA1c levels over time, reflecting ongoing improvement in glycemic control throughout the study.
- Cost Trend (Years 1-3): The cost increased by 15% annually during the first three years of the program, which may be due to the initial investment required for the program's implementation.
- Cost Trend (Years 4-12): After the initial three years, the cost increase stabilized to 3% annually, indicating that the program's costs became more predictable and controlled over time.

Table 4 Cost-Benefit Analysis:

Measure	Value
Net Present Value (NPV)	₹ 1.5 million
Benefit-Cost Ratio (BCR)	1.8
Return on Investment (ROI)	80%

- Net Present Value (NPV): The positive NPV of ₹ 1.5 million indicates that the program is financially viable, meaning the benefits of the program outweigh the costs when adjusted for the time value of money.
- Benefit-Cost Ratio (BCR): A BCR of 1.8 suggests that for every ₹ 1 spent on the program, ₹ 1.80 is gained in benefits, further reinforcing the financial viability of the program.
- Return on Investment (ROI): An ROI of 80% indicates a substantial return, showing that the program not only recovers its costs but also generates significant additional value.

Table 5 Cost-Effectiveness Analysis:

Measure	Value
ICER	₹ 120,000 per QALY
QALYs Gained	2,500 over 12 years

- ICER: The Incremental Cost-Effectiveness Ratio (ICER) of ₹ 120,000 per QALY gained is within a reasonable range, indicating that the program is cost-effective according to common thresholds.
- QALYs Gained: The program resulted in 2,500 QALYs gained over 12 years, which is a substantial health benefit for the population involved.

Table 6 Comparative Statistics

Measure	**Mean Difference (95% CI)**	**p-value**
HbA1c Reduction	**-1.1% (-1.3 to -0.9)**	**< 0.001**
Microvascular Complications Reduction	**30%**	**< 0.001**
Macrovascular Complications Reduction	**25%**	**< 0.01**

- HbA1c Reduction: The mean difference of -1.1% in HbA1c, with a 95% confidence interval of -1.3 to -0.9 and a p-value of < 0.001, shows a statistically significant improvement in glycemic control as a result of the program.
- Microvascular Complications Reduction: A 30% reduction in microvascular complications with a p-value of < 0.001 indicates a significant decrease in diabetes-related microvascular complications due to the intervention.
- Macrovascular Complications Reduction: A 25% reduction in macrovascular complications with a p-value of < 0.01 also shows a significant improvement, reducing the risk of major cardiovascular events among patients.

Table 7 Regression Analyses:

Factor	β Coefficient	p-value
Age	-0.03	< 0.05
Baseline HbA1c	0.15	< 0.001
Adherence to Program	0.25	< 0.001

- Age: The negative β coefficient of -0.03 with a p-value of < 0.05 indicates that younger patients are more likely to benefit from the program in terms of cost-effectiveness.
- Baseline HbA1c: A β coefficient of 0.15 with a p-value of < 0.001 shows that patients with higher baseline HbA1c levels are likely to experience greater improvements in cost-effectiveness, possibly due to larger reductions in HbA1c.
- Adherence to Program: The β coefficient of 0.25 with a p-value of < 0.001 highlights that better adherence to the program significantly predicts better cost-effectiveness, emphasizing the importance of patient compliance.

Table 8 Survival Analysis:

Group	Median Time to First Complication	p-value
Intervention Group	8.5 years	< 0.001
Historical Control	6.2 years	

- Median Time to First Complication:
- Intervention Group: The median time to the first complication is 8.5 years, significantly longer than the historical control.
- Historical Control: The median time to the first complication is 6.2 years. The p-value of < 0.001 indicates that the intervention significantly delayed the onset of diabetes-related complications.

Table 9 Multivariate Analysis:

Component	Variance Explained (%)
Glycemic Control	30%
Treatment Adherence	25%
Socio-economic Factors	20%

- Glycemic Control: Explains 30% of the variance, indicating it is the most significant factor contributing to the success of the program.
- Treatment Adherence: Explains 25% of the variance, suggesting it is a key driver of positive outcomes.
- Socio-economic Factors: Explains 20% of the variance, highlighting the importance of Socio-economic status in the program's effectiveness.

Table 10 Economic Modeling

Measure	Value
Projected 12-Year Cost Savings	₹ 1.8 million

- Projected 12-Year Cost Savings: The projected savings of ₹ 1.8 million over 12 years suggests that the program will result in substantial long-term cost savings.

Table 11 Sensitivity Analysis

Analysis Type	Key Finding
One-Way Sensitivity	Sensitive to medication costs, complication rates
Probabilistic Sensitivity	95% CI that ICER < ₹ 200,000 per QALY

- One-Way Sensitivity: The program’s results are most sensitive to changes in medication costs and complication rates, indicating these factors have the most significant impact on the cost-effectiveness.
- Probabilistic Sensitivity: With a 95% confidence that the ICER remains below ₹ 200,000 per QALY, the analysis confirms that the program is likely to remain cost-effective under various scenarios.

Table 12 Quality of Life Analysis

Measure	**Mean Improvement (95% CI)**	**p-value**
EQ-5D Score	**0.15 (0.12 to 0.18)**	**< 0.001**

- EQ-5D Score: The mean improvement of 0.15 in the EQ-5D score, with a 95% confidence interval of 0.12 to 0.18 and a p-value of < 0.001, indicates a statistically significant and clinically meaningful improvement in patients' quality of life over the study period

Table 13 Summary of Patient Responses

Statements	Response Options	Percentage (%)
Have been diagnosed with diabetes	Less than 1 year	15%
	1-5 years	40%
	6-10 years	25%
	More than 10 years	20%
HbA1c level at the start of the program	Below 7%	10%
	7% - 8%	50%
	8% - 9%	30%
	Above 9%	10%
Current HbA1c level	Below 7%	30%
	7% - 8%	40%
	8% - 9%	20%
	Above 9%	10%

Table 13, observe significant variations in patients' diabetes histories and glycemic control. The majority of patients (65%) have been living with diabetes for 5 years or less, while a notable portion (20%) has managed the condition for over a decade. Initially, only 10% of patients had their HbA1c levels under optimal control (below 7%), with half the group falling in the 7-8% range. However, the current HbA1c data reveals a positive trend in glycemic management. The percentage of patients achieving optimal control has tripled to 30%, and there's been a 10% increase in those maintaining levels between 7-8%. Concurrently, the proportion of patients with HbA1c levels above 8% has decreased from 40% to 30%. This improvement suggests that the program or interventions implemented have been effective in helping patients better manage their blood glucose levels, although there remains room for further progress.

Table 14 Summary of Program Experience and Outcomes

Statement	Response Options	Percentage (%)
Satisfied with the diabetes care program	Very Satisfied	50%
	Satisfied	30%
	Neutral	10%

Statement	Response Options	Percentage (%)
	Dissatisfied	5%
	Very Dissatisfied	5%
Rate the quality of care received	Excellent	60%
	Good	30%
	Average	10%
Attend follow-up appointments	Monthly	25%
	Every 3 months	50%
	Every 6 months	15%
	Annually	10%
Experienced any diabetes-related complications	Yes	20%
	No	80%
Overall quality of life since starting the program	Significantly improved	55%
	Improved	40%
	No change	5%

Table 14 presents an overview of patient experiences and outcomes regarding a diabetes care program. A significant portion of patients (80%) are satisfied with the program, with 50% expressing they are "Very Satisfied" and 30% "Satisfied." Most patients rate the quality of care received as "Excellent" (60%) or "Good" (30%). Follow-up appointments are predominantly scheduled every three months (50%), with 25% attending monthly. A minority (20%) have experienced diabetes-related complications, while the majority (80%) have not. In terms of overall quality of life since joining the program, 55% report it has "Significantly Improved," and 40% say it has "Improved," reflecting positive outcomes from the program.

Table 15: Summary of Patient Expenditures on Diabetes Management

Expenditure Category	Response Options	Percentage (%)
Average Monthly Expenses	Less than ₹1,000	40%
	₹1,000 - ₹3,000	50%
	₹3,001 - ₹5,000	20%
Medication Costs	Less than ₹500	45%
	₹500 - ₹1,000	40%
	₹1,001 - ₹2,000	15%

Expenditure Category	Response Options	Percentage (%)
Consultation Fees	Less than ₹300	25%
	₹300 - ₹600	50%
	₹600 - ₹1,000	15%
	More than ₹1,000	10%
Dietary Expenses (Specialized Diet)	Less than ₹500	25%
	₹500 - ₹1,000	40%
	₹1,001 - ₹2,000	25%
	More than ₹2,000	10%
Additional Health Services	Less than ₹300	30%
	₹300 - ₹600	40%
	₹600 - ₹1,000	20%
	More than ₹1,000	10%
Financial Difficulties	Yes	15%
	No	85%

Table 15 details patient expenditures related to diabetes management. Monthly expenses for managing diabetes are predominantly in the range of ₹1,000 - ₹3,000 for 50% of patients, with 40% spending less than ₹1,000. Medication costs are relatively low, with 45% spending less than ₹500 and 40% between ₹500 and ₹1,000. Consultation fees for most patients fall between ₹300 and ₹600 (50%), while 25% spend less than ₹300. Dietary expenses are split among various ranges, with 40% spending between ₹500 and ₹1,000. Most patients (85%) do not experience financial difficulties, indicating that, for the majority, diabetes management costs are manageable.

Table 16 Financial Impact and Value Perception

Statement	Response Options	Percentage (%)
Costs Justified by Health Outcomes	Strongly Agree	40%
	Agree	35%
	Neutral	15%
	Disagree	5%
	Strongly Disagree	5%
Value of Specialized Diabetes Care Program	Excellent	50%

Statement	Response Options	Percentage (%)
	Good	30%
	Average	15%
	Poor	5%
Suggested Improvements to Reduce Financial Burden	Subsidized medication	40%
	Lower consultation fees	35%
	Nutritional support programs	25%

Table 16 assesses the financial impact and perceived value of the diabetes care program. A substantial number of patients feel that the costs are justified by the health outcomes, with 75% either "Strongly Agreeing" (40%) or "Agreeing" (35%). The value of the specialized diabetes care program is viewed positively by most patients, with 50% rating it as "Excellent" and 30% as "Good." To alleviate financial burdens, patients suggest improvements such as subsidized medication (40%), lower consultation fees (35%), and nutritional support programs (25%). These suggestions reflect the areas where patients feel enhancements could further support their diabetes management efforts.

Findings

1. Effectiveness of the Diabetes Care Program:

- Glycemic Control: The diabetes care program significantly improved patient glycemic control, as evidenced by the reduction in mean HbA1c levels from 8.2% at baseline to 7.1% at the end of the study (Table 2). This translates into a consistent annual improvement in glycemic control, with a trend coefficient of -0.092% per year (Table 3).
- Reduction in Complications: There was a notable reduction in both microvascular and macrovascular complications, with reductions of 30% and 25%, respectively (Table 6). This suggests that the program effectively mitigates diabetes-related health risks.

2. Cost-Effectiveness and Financial Impact:

- Cost-Effectiveness: The program demonstrated cost-effectiveness, with an Incremental Cost-Effectiveness Ratio (ICER) of ₹120,000 per Quality-Adjusted Life Year (QALY) and 2,500 QALYs gained over 12 years (Table 5). This is within a reasonable range, indicating good value for money.
- Financial Viability: The positive Net Present Value (NPV) of ₹15 million, Benefit-Cost Ratio (BCR) of 1.8, and Return on Investment (ROI) of 80% (Table 4) highlight that the program is financially viable and generates substantial economic benefits.

3. Patient Satisfaction and Quality of Life:

- Satisfaction: A majority of patients reported high levels of satisfaction with the program, with 50% being "Very Satisfied" and 30% "Satisfied" (Table 14). Most patients also rated the quality of care as "Excellent" (60%).
- Quality of Life: The program led to a significant improvement in patients' quality of life, with a mean EQ-5D score improvement of 0.15 (Table 12).

4. Economic Modeling and Projections:

- Cost Savings: The projected 12-year cost savings of ₹1.8 million (Table 10) indicate that the program is expected to result in substantial long-term financial savings.

5. Patient Expenditures and Financial Impact:

- Expenditures: Most patients spend between ₹1,000 and ₹3,000 monthly on diabetes management, with medication and consultation costs being manageable for the majority (Table 15). Financial difficulties are reported by only 15% of patients.
- Value Perception: 75% of patients believe that the costs of the program are justified by the health outcomes (Table 16), and 80% rate the value of the program positively.

Suggestions

To further reduce financial burdens, subsidizing medication and other costs could make the program more accessible to lower-income patients (Table 16). This could help increase adherence and overall program effectiveness.
Increasing the frequency and accessibility of follow-up appointments could potentially enhance adherence and allow for earlier interventions, leading to even better health outcomes.
Given the initial cost increase of 15% annually (Table 3), strategies to control or reduce startup costs could improve the financial sustainability of the program. Streamlining resource allocation and negotiating lower costs for essential supplies might be effective measures.
The positive findings regarding cost-effectiveness and patient outcomes suggest that the program has the potential for scalability. Expanding similar programs to other regions in India or similar contexts could help address the broader diabetes management challenges.
Tailoring program components to fit the specific needs of different Socio-economic and cultural groups could enhance effectiveness and sustainability in varied settings.
Given that higher baseline HbA1c levels are associated with greater improvements (Table 7), targeted interventions for patients with higher initial levels could be prioritized to maximize overall program impact.
Regularly incorporating patient feedback and addressing suggestions for improvements, such as nutritional support programs (Table 16), can help refine the program and ensure it remains responsive to patient needs.
Further research is needed to explore the long-term effects and economic impact of such programs in different settings. Longitudinal studies could provide deeper insights into the sustainability and broader applicability of specialized diabetes care programs.

Conclusion

This study concluded that diabetic patients are spending a minimum level of money from their income on diabetes management. The study was analyzed and examined at Bose Hospital in Tirunelveli. The majority of diabetic patients surveyed opined that their expenditure is at a very minimum level, and they also receive special care as patients. Furthermore, this study revealed that Bose Hospital in Tirunelveli takes measures to control diabetes and provides special care for its patients. The hospital offers comprehensive diabetes management programs, including regular check-ups, personalized treatment plans, and patient education on lifestyle modifications. Additionally, the study highlighted the importance of affordable healthcare in managing chronic conditions like diabetes, emphasizing the need for continued research on the long-term economic impact of diabetes care in the region.

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