Are Extreme Events a Crisis or Catalyst for Sustainable Urban Water Management? The Case of two Australian Cities

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ABSTRACT
It is widely accepted that new, more sustainable approaches to urban water management are required if cities and ecosystems are to become resilient to the effects of growing urban populations and global warming. Climate change predictions show that it is likely that cities around the world will be subject to an increasing number of extreme and less predictable events including flooding and drought. Historical transition studies have shown that extreme events can expedite the adoption of new practices by destabilising existing management regimes and opening up new windows of opportunity for change. Yet, they can also act to reinforce and further entrench old practices. This case study of two Australian cities responding to extreme water scarcity reveals that being unprepared for extremes can undermine progress towards sustainable outcomes. The results showed that despite evidence of significant progress towards sustainable urban water management (SUWM) in Brisbane and Melbourne, the extreme water scarcity acted to reinforce traditional practices at the expense of emerging sustainability niches. Drawing upon empirical research and transitions literature, recommendations are provided for developing institutional mechanisms that are able to respond proactively to extreme events and be a catalyst for SUWM when such opportunities for change arise.

KEY WORDS
Sustainability; extremes; transitions; adaptive, integrated management

INTRODUCTION
Across Australia and internationally, cities and urban centres are facing a range of serious challenges related to water management. Despite the many benefits from traditional urban water management approaches (such as widespread access to clean drinking water, flood control and the protection of public health through wastewater management) the modes of delivering these services are now inflicting serious environmental costs such as pollution of waterways and greenhouse gas emissions. In spite of common agreement about the need for more sustainable urban water management (SUWM), multiple commentators believe that the existing urban water regime poses significant barriers to change. They argue that rigid government control mechanisms reinforce the compartmentalisation of infrastructure and service provision, leaving the sector ill equipped for responding and adapting to complex, sustainability challenges (Marsalek et al. 2001; Newman, 2001; Brandes and Kriwoken, 2006; Wong, 2006).

Concepts of adaptive and integrated management offer an alternative to the traditional urban water regime, providing insights into some of the governance factors likely to support more sustainable practices. SUWM regimes would emphasise a systems approach whereby interconnections between the management of each of the water streams (and other related functions such as land use planning) would deliver and protect multiple benefits. They would also be adaptive and ready to respond to unanticipated outcomes by being prepared for multiple potential future conditions. Therefore, investing in a level of strategic redundancy would be part of a resilient system. Such an approach is somewhat at odds with traditional urban water management whereby the most likely future condition (i.e. water scarcity) is often optimised; leaving systems vulnerable to future change (i.e. water abundance) (Pahl-Wostl, 2008). Following a review of the literature, Table 1 below broadly lists the attributes of the traditional urban water regime and the proposed attributes of a SUWM regime (Newman, 2001; Maksimovic´ and Tejada-guibert, 2001; Mitchell, 2005; Mostert, 2006; Pahl-Wostl, 2008):

Table 1. Attributes of Traditional and Sustainable Urban Water Management Regimes

Attributes	Traditional Regime	Sustainable Regime
System Boundary	Water supply, sewerage and flood control for economic and population growth and public health protection.	Multiple purposes for water considered over long-term timeframes including waterway health and other sectoral needs i.e. transport, recreation/amenity, micro-climate, energy etc.
Management Approach	Compartmentalisation and optimisation of single components of the water cycle	Adaptive, integrated, sustainable management of the total water cycle (including land-use)
Expertise	Narrow technical and economic focussed disciplines	Interdisciplinary, multi-stakeholder learning across social, technical, economic, design, ecological spheres etc
Service delivery	Centralised, linear and predominantly technologically and economically based	Diverse, flexible solutions at multiple scales via a suite of approaches (technical, social, economic, ecological etc)
Role of public	Water managed by government on behalf of communities	Co-management of water between government, business and communities
Risk	Risk regulated and controlled by government	Risk shared and diversified via private and public instruments

The critical need for a transition towards SUWM is exacerbated considering the risks posed to cities from climate change and population growth. In 2007, urban populations surpassed those in rural environments for the first time on record, placing further pressure on already stressed water resource. Additionally, climate change predictions show that extreme drought and flooding events in cities will be less predictable and more frequent (IPCC, 2007) highlighting the importance for cities to be ecologically and institutionally resilient.

Historical studies have shown that extreme events, such as those highlighted in the climate change predictions, are sometimes the catalyst for significant socio-technical transitions (i.e. radical shifts in technology/infrastructure systems and the ways in which society values and interacts with them) as they can be important for opening up a window of opportunity for enabling change (see Geels, 2002; Geels and Schot, 2007). However, these studies also reveal that if there is not a viable alternative to the dominant regime at the timing of the extreme event, then this event will reinforce and further entrench existing practice and often 'old' institutional values.

This paper presents the results of a social research project investigating how the response of urban water regimes to extreme events has affected progress towards SUWM. The research involved a 2006/07 case study of two Australian cities: Melbourne and Brisbane, and how the urban water management regimes in these cities responded to an extreme event - unprecedented water scarcity. Despite evidence of significant progress towards SUWM in both cities prior to the extreme event, the regime responses to a perceived crisis acted to reinforce traditional practice at the expense of the new more sustainable practices being developed. Given the likelihood that cities will face an increasing number of extreme events, this papers draws upon the insights from these case studies to help inform a series of recommendations around developing adaptive and integrated institutional mechanisms that are able to respond proactively to extreme events and utilise the inherent opportunities to expedite SUWM.

Socio-technical Transitions - Social Theory for Understanding Regime Change

'Transition theory' is a relatively new area of scholarship, arising out of the integration of new institutionalism, innovation studies and the sociology of technology. Work by Geels (2002) and others offers promising insights for understanding the architecture of transitions from one dominant type of socio-technical system to another and has been identified as one of the most promising areas of scholarship for advancing sustainable development (Meadowcroft, 2005). Through analysis of historical investigations into major transitions, such as from the 'horse and cart to the automobile' and from the 'cesspool to the sewer,' Geels has built upon previous reserach to advance the multi-level concept, which describes three nested levels of social structure where change can occur. He argues that major transitions are brought about via the interactions between processes at these three levels whereby changes within one or more levels can stimulate change at the other levels:

- *Macro-level – Landscape*: incorporates dominant cultures and worldviews as well as the natural environment and large material systems such as cities. Change at this level is generally slow (decades and generations) and often beyond the direct influence of individual actors or organisations and might include changes in population dynamics, political models, macro economics and/or environmental conditions.
- *Meso-level – Regime*: comprises interconnected communities of practice with aligned activities who operate according to formal and informal rules and norms, which are maintained to deliver economic and social outcomes. The urban water regime in Australia would be typically populated by water authorities, regulators, state and local governments, land developers, consulting organisations, manufacturers, academic institutions, community groups and professional bodies. Change at this level is thought to move in decades.
- *Micro-level – Niche*: is an emergent space for developing products, processes and technologies that are substantially different from the status quo. These innovation spaces are fostered and protected from the dominant regime by a small network of dedicated actors, sometimes operating outside of the dominant regime. Changes at this level are the most rapid and can occur in months and years.

Niches at the micro-level and regimes at the meso-level are similar kinds of structures whereby they are both driven by communities of interacting groups. However, at the regime level, these are large and stable with well established rules and norms whereas at the niche level they are small and relatively unstable. Niche innovations can become regimes when social networks grow larger and rules become more stable. Landscape developments do not operate according to the same set of sociological processes and instead exert deep-structural influences upon regimes and niches making some activities easier than others.

Current research reveals that there are likely to be multiple possible transition pathways involving processes within the three levels (see: Geels and Schot, 2007). Nonetheless, the major ingredients involved in a socio-technical transition are: (a) changes at the landscape level creating pressure on the regime; (b) niches developing new and innovative technologies and/or processes; and (c) destablisation of the regime allowing niche innovations to break through and compete with the existing regime. A transition has occurred when the regime has transformed from one stable state to another and all three levels of social structure mutually support the new technology and/or process and associated practice. The nature of the transition pathway will depend upon the strength, speed, scope and frequency of the landscape pressure; the stability of the regime and its ability to respond to the landscape pressure; and the level of development of the niche innovations. In other words, the timing and nature of the interactions between the three levels will influence the type of transition pathway that will occur and the extent to which the regime will need to change. Studies of past transitions have shown that sometimes an extreme event (at the landscape level) has been required to destabilise the existing regime and enable niche innovations to break through inducing a transition to another socio-technical system state. However, the research also reveals that if there is not a viable niche alternative to the dominant regime at the timing of the extreme event, then this event can reinforce and further entrench existing practice and often 'old' institutional values.

Given that leading thinking in SUWM strongly suggests the need for a new urban water regime (see Table 1), then understanding existing transition opportunities caused through extreme events and other landscape developments will be essential, particularly given most cities will experience extremes and transition theory highlights the significant risk of further embedding past practices.

METHODS

The results reported here are part of a broader program of research aimed at understanding the barriers and drivers to SUWM in several Australian cities. While the research was not originally designed for the explicit analysis of the impact of extremes, the opportunity to investigate two city-wide responses to an extreme event arose when, during and after the data collection phases, Brisbane and Melbourne were subject to extreme water scarcity. This context provided a unique opportunity to retrospectively engage with the research question - *How do urban water regimes respond to extreme events and how does this affect progress towards SUWM?*

Brisbane and Melbourne were selected from the cases investigated as part of the broader research because they were both considered leading cities in SUWM prior to the onset of extreme drought conditions. Through various forums, both cities were recognised for the innovation of technical solutions and progressive institutional mechanisms (as highlighted in the case study results below). In studying the impact of an extreme event, it was important to select pro-active SUWM city case studies to understand the inherent risks and/or drivers for SUWM.

The research involved a detailed analysis of city-wide responses to extreme water scarcity across Brisbane and Melbourne, drawing upon the synthesis of socio-technical transitions theory and principles of SUWM as an analytical framework. The analysis focused on charting the recent urban water histories for each city, mapping the current institutional systems and rules, and assessing the stakeholder influences, perspectives and values. The research drew on the collection and synthesis of multiple sources of evidence including primary and secondary data. Primary data was gathered in 2006 involving in-depth interviews with 167 senior to middle management urban water professionals (93 in Melbourne and 74 in Brisbane). Interview respondents represented a diversity of experiences, responsibilities and perspectives including representatives from state and local government agencies, water utilities, regulators, consultants, developers, research institutions, and non-government organisations. It was important to understand their perspectives because they represented the traditional urban water regime and some were also involved in new sustainability focussed niches. Each interview comprised between one and four practitioners who were asked a set of semi-structured questions designed to generate discussion on the current barriers and drivers to SUWM and the interventions required to enable a transition to more sustainable practices. The primary data was cross-referenced with secondary data sources including policy, media, organisational and other forms of industry literature, in addition to existing scientific literature in the field. The analysis process involved seeking contradictory and converging evidence and alternative meanings to emerging explanations and findings. Interview results were contrasted and compared in terms of key themes that arose which allowed for disparities in accounts to be further investigated and clarified. Research findings were validated in late 2007 by a series of focus groups and an industry workshop with key urban water professionals in each city.

CASE STUDY RESULTS

The Brisbane Case

Case Study Context. The City of Brisbane, located on the coast of South East Queensland (SEQ), Australia, is currently the third largest and fastest growing city in Australia. During the interviews, SEQ was in its longest drought period in recorded history and dams were at historically low levels. Brisbane received only two-thirds of its normal annual rainfall total in 2006 and in 2007 dams dropped below 20% of their capacity. During and prior to the research, Brisbane's formal water management was primarily under the jurisdiction of Brisbane City Council (BCC), the largest local government organisation in Australia with responsibilities for the city's water policy and service provision across the water cycle. A government water corporation provided bulk water supplies to BCC and a number of state government departments had regulatory and regional planning responsibilities.

Pre-extreme Event. The research revealed that over the last 30-40 years an active 'waterway health' niche had emerged in Brisbane, focussed on expanding the regime's 'system boundary' by advocating new approaches to water management and urban design in order to protect receiving waterway health. It had been successful in influencing and shifting the dominant regime in a number of key ways particularly via investment in rigorous science, prolonged advocacy, strong political support and strategic partnerships to build awareness and ownership across the sector. Many of the attributes represented by this niche reflected the envisaged attributes of a SUWM regime (see Table 1). For example, the 'management approach' adopted by this niche was via an interconnected and inter-disciplinary voluntary partnership between government, community, industry and researchers throughout SEQ to improve the health of waterways and catchments. A multi-stakeholder learning network was supported by a bridging organisation responsible for science communication and capacity building, as well as setting strategic policy goals and waterway health targets. By the time of our research in 2006, the new values and practices being espoused by this niche had gained strong political support and partially diffused across the traditional urban water regime whereby both BCC and state government departments had committed to the protection of waterways through stormwater quality management performance targets and there had been significant investment in upgrading polluting sewerage infrastructure as well as investment in new stormwater quality treatment technologies such as wetlands and bio-filtration systems, some of which was funded by a BCC environmental levy.

A less established niche around diverse water sources had also been emerging, once again seeking to expand the regime's 'system boundary' and 'service delivery' functions to implement a range of new decentralised water supply technologies such as stormwater harvesting, rainwater tanks and sewer mines. Despite some progress, these technologies were still far from mainstream practice and there had been less success with large centralised alternative water sources such as sewage recycling.

A number of advocates from the two niches had recently begun advocating a total water cycle management (TWCM) approach, seeking new integrated solutions that could deliver benefits to multiple parts of the water cycle via a series of structural and non structural means. This group had successfully influenced BCC to institute the first Australian TWCM policy group involving 45 policy staff charged with developing integrated urban water policy across the water cycle.

Post Extreme Event. In response to the extreme water scarcity, the state government announced an AU$9billion 'water grid', linking water supplies across SEQ including new dams, desalination and recycled sewage from Brisbane. Associated with the new infrastructure was a proposed new institutional model removing the water supply and sewerage functions from BCC and other SEQ local governments, to be replaced by a series of government owned water corporations (focused upon supply and sewerage). Community water restrictions involving the unprecedented banning of all outdoor hosing were also introduced, supported by rebates for rainwater tanks and water efficient household appliances with widespread community uptake.

Interview respondents attributed the extreme water scarcity with driving the adoption of more diverse water supplies, which had previously struggled to break into the market, such as recycled sewage. It was also seen to have increased the community's engagement with water conservation techniques and the uptake of localised water supply technologies at a household scale such as rainwater tanks and greywater systems. However, the institutional response to the drought, namely the proposed 'water grid' and associated governance model, attracted criticism from 71 of the 74 Brisbane interviewees who believed that the grid solution was a political response to a crisis that represented a significant missed opportunity for sustainable change. Rather, it was seen to deal with only one future water scenario, that being water scarcity, at the expense of the total water cycle and hence represented a direct narrowing of the 'system boundary'. The underpinning critique was that investment in the traditional supply security agenda represented a step back to the traditional regime 'service delivery' model via large, permanent, energy intensive water supply infrastructure when climate change predictions forecast variability and uncertainty and periods of water abundance, requiring integrated, flexible and adaptive solutions that were responsive to the climate, waterways and energy contexts.

There was significant concern that restructuring institutional arrangements around such a narrow part of the water cycle would increase the risks of poor management of other parts of the water cycle. Professionals involved in the waterway protection niche were concerned that much of the work they had undertaken was losing institutional attention and focus. Those in the diverse water supplies niche (despite general endorsement of the sewage recycling scheme as a positive outcome for sustainability) worried that the broad scale investment in large centralised infrastructure would act as a disincentive for investment in localised, decentralised infrastructure that was more sensitive to flooding, waterway health and micro-climate needs (such as stormwater and rainwater harvesting).

The perceived need for a quick political response was seen to have resulted in a closed planning process without adequate opportunity for intellectual debate and public appraisal.

This reflected the traditional ‘role of the public’ rather than the more participatory co-management approach that had recently begun to emerge. Additionally, many interviewees believed that the water grid solution was driven largely by professionals not traditionally involved in water management but rather those involved in political advisory roles and the energy sector. There was concern that this lack of engagement with the broader urban water professional community resulted in a limited assessment and comprehension of current water problems and possible solutions. However, despite widely-held reservations about the longer term sustainability implications of the solution, respondents felt there would be few professionals or associations that would have the ‘courage’ to raise public objections to the proposal when the community and politicians were wanting an immediate response to the crisis.

The Melbourne Case

Case Study Context. The coastal city of Melbourne is the second largest city in Australia, with a rapidly expanding population relying entirely upon surface water supplies. At the time of the research, the State government set the water policy and regulatory framework with services delivered by corporatised state government own water businesses responsible for water supply and sewerage, regional drainage and waterway health. Thirty-eight local government authorities had responsibilities for local drainage networks and some regulatory functions. Melbourne had been experiencing low-level water supply stress for many years but water scarcity had not reached the same extreme level as in Brisbane, however, after the completion of the interviews, water scarcity became acute with dams reaching just over 20% of their capacity in 2008.

Pre Extreme Event. Similar to Brisbane, a strong niche around waterway health protection had developed in Melbourne, successfully influencing the traditional regime to the point that the city was now internationally recognised in various forums as a leader in stormwater quality management. Niche advocates had employed similar strategies to those used in Brisbane via investment in rigorous science, advocacy and partnerships and this niche also displayed many of the attributes of a SUWM regime through expanding the ‘system boundary’ and advocating a new more integrated ‘management approach’. The Melbourne waterway niche had also developed innovative financial and risk management approaches for enabling ‘risk’ to be shared between multiple stakeholders. In one example of the Lynbrook housing development, a developer agreed to provide land and one of the government water corporations underwrote the risk for the implementation of a series of innovative stormwater quality treatment technologies promising to rebuild with traditional infrastructure if the project failed. The project was also underpinned by an integrated and adaptive learning model whereby the project was extensively monitored and scientifically assessed by a local university which considered the multi-faceted spheres of project implementation including technical performance, economic effects, policy tools and the social context, feeding research findings into the project development process on an ongoing basis. This provided important knowledge for future co-management initiatives with the public. The project went on to become an internationally recognised example of water sensitive urban design which was identified by interview respondents from across Melbourne and Brisbane as a key policy and technical learning tool.

Capacity building was a key focus of the waterways niche which formed a multi-stakeholder learning network via a partnership organisation between local and state government and the private sector responsible for providing training and guidance to practitioners around scientifically informed, best practice stormwater quality management. By the time of the research, the traditional regime had shifted to the extent that stormwater quality performance targets were mandated for all new residential subdivisions.

There was also an active niche around diverse water sources that had been successful in expanding the urban water 'system boundary' and gaining strong political support for research and development around a range of decentralised alternative water supplies including the use of 3rd pipe technologies, rainwater tanks, sewer mining and rainwater tanks. Unlike Brisbane, Melbourne also had a well established water conservation niche which had been proactive in the introduction of permanent water conservation measures for household water uses prior to the onset of extreme water scarcity, with a particular focus on building a sense of individual responsibility for water sensitive behaviours in contrast to the tradition 'role of the public.'

Much of the focus in the Melbourne interviews was around the perceived barriers to the widespread adoption of SUWM practices, which mostly related to institutional inertia and the dominance of the traditional regime. While there was a reasonably high level of awareness about climate change and population growth projections, there was a general lack of concern about the impact from extreme events. Indeed, several respondents believed that a water supply crisis may be required to shift the traditional regime and induce more sustainable practices. Overall, most professionals believed that it would be several years (some believed about 25 years) before the city would be faced with extreme water scarcity.

Post Extreme Event. When extreme water scarcity did eventuate in Melbourne, just months after the interviews, the institutional response mirrored that of Brisbane's involving a politically driven multi-billion dollar investment in centralised, energy intensive water supply infrastructure (including desalination and an inter-connected pipeline) and an institutional review focused upon optimising supply security and therefore a significant narrowing of the 'system boundary'. In follow-up focus groups with interviewees, they expressed similar disillusionment to their Brisbane counterparts about what they saw as a weakening of recent sustainability initiatives driven by the niches and the further entrenchment of unsustainable practices in the dominant regime.

KEY INSIGHTS AND DISCUSSION

Analysing the results from the perspective of transition theory reveals that prior to the onset of extreme water scarcity; both Brisbane and Melbourne had been undergoing incremental change towards SUWM. Macro-level pressure on the regime from the social movement of modern environmentalism, ongoing waterways degradation and increasing levels of water scarcity, had stimulated the development of active niches around 'waterway health protection', 'diverse water supplies' and 'water conservation'. These niches were attempting to not only introduce a new set of values and practices around environmental protection; they were also seeking to radically change traditional practices so that they no longer inflicted negative social and environmental outcomes (such as waterways degradation, reduced social amenity and rigid government control). Drawing upon the attributes of SUWM regimes, as presented in Table 1, the techniques employed by these niches embodied some of the proposed attributes of adaptive and integrated regimes. While these attributes had not diffused across the entire urban water regime in either city, their influence had grown significantly over the last few decades and particularly over the last 5-10 years.

The onset of extreme water scarcity appears to have opened up a window of opportunity for expediting change, with significant political attention and financial support directed to the sector. However, the results indicate that the existing sustainability niches were not able to capitalise on this opportunity. Instead, when drought occurred, the prevailing system overrode the new values and practices being institutionalised by these networks and re-entrenched the traditional urban water regime (although perhaps only temporarily, as time may show). The outcome was a narrowing of the institutional focus away from the new integrated processes attempting to span the total water cycle back to a directive and narrow approach representing a shift back to a more traditional 'system boundary', 'management approach' and 'service delivery' model. The regime response to the drought was focussed solely upon optimising water supply which catered largely for one possible scenario – water scarcity and failed to take account of other possible future scenarios (such as water abundance and flooding) or include consideration of other essential parts of the water cycle such as waterway health protection. Additionally, the response in both cities was largely politically driven with limited opportunities for input from the wide spectrum of urban water practitioners and experts, although this appeared to be more overt in Brisbane. Overall, the results show that the drought had acted largely as a major setback to the existing momentum of the niches which have since been required to employ greater strategic effort and advocacy to advance SUWM.

So, what went wrong? The new SUWM niches had largely evolved from the aspects of water cycle management that are not privileged by the traditional urban water regime and had therefore suffered from a lack of mainstream political support. While the niches had been extremely successful in building up rigorous science and technical innovations and raising the receptivity of urban water professionals to new more sustainable approaches, they had been less successful in building awareness and receptivity amongst senior bureaucrats and politicians. When politicians and their senior aides were seeking a rapid solution to a perceived crisis, the niches were unable to build the required level of political receptivity in such a short time-frame. The implication from this research is that it will be important for sustainability niches to be prepared for the onset of future extreme events if extremes are to be harnessed to expedite SUWM. Drawing upon the insights from the case studies we propose a series of recommendations for preparing for the onset of extremes:

- Active niche building is required as an explicit policy process whereby opportunities are provided for the trialling and innovation of new technologies and processes that are not currently supported by the traditional regime. This will require recognition and understanding that these new products and processes will not necessarily be the most efficient or optimum approach but that their value is in their long-term potential to ensure resiliency and adaptive capacity.
- Niche based sustainability advocates will need to prepare transitions strategies underpinned by an awareness and acceptance that extreme events have the potential to not only drive change, but also to generate a captured response whereby political processes and traditional practices can override current best practice thinking. To avoid this, sustainability niches will need to have developed sufficiently robust alternatives to dominant practices combined with strong strategic links into the regime and a level of positive political receptivity (see Brown and Keath, 2008) across the sector so that when extreme events arise, the new practices can be rapidly diffused.
- Regimes will need to envisage and plan for multiple future scenarios, which will involve acknowledgement of extremes and ultimately require a level of redundancy in the system.
- Urban water professionals need to be critically informed and valued by decision makers and politicians via involvement in multi-stakeholder, adaptive learning mechanisms.

While integrated and adaptive governance processes will be essential for achieving SUWM, the results suggest that in times of crisis broad, collaborative, multi-stakeholder processes appear to be less likely. Therefore, a key question for future research will be to understand what are the factors required for enabling integrated decision making in times of crisis?

CONCLUSION

In making change towards SUWM a delicate balance is required between de-stabilising the existing regime and ensuring resilience of new sub-regimes. This paper demonstrates the risks to SUWM niches from being unprepared for the onset of extreme events. Given the likelihood of more frequent and extreme flooding and drought conditions under climate change predictions, it appears that if SUWM is to be achieved, it will be essential that new sustainability niches are adequately prepared to capitalise on the opportunities for change inherent in extremes. Additionally, traditional urban water regimes will need to develop the institutional incentives and capacity to respond and adapt to extreme events by utilising the innovations being fostered within sustainability niches. While further research is required to understand the factors that enable integrated decisions in times of crisis, there is much that can already be done in terms of building the resilience and institutional influence of niches in preparation for future windows of opportunities for change.

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